Northern B.C.
Wolf - Caribou Study

- a comparative analysis of caribou calf recruitment in an experimental wolf removal and control area

Draft Report

by

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January 1984

PREFACE

This report on the northern B.C. wolf/caribou study is in draft form. Four items will be incorporated in the final version: suggestions received from reviews by technical experts, a mathematical population model, recommendations for future research and management, and the 1983 fall census data from both study areas. These latter data indicate that both herds declined during 1982-83.

ABSTRACT

In 1977, a project began in northern British Columbia in order to determine the effect of reducing wolf numbers upon the recruitment of caribou calves. On one area, the Horseranch Range, wolves were reduced by 61-80% from pre-control numbers during 1978-80. Comparisons of wolves and caribou were made with another caribou range, the Level Mountain Range, where wolves were not reduced. Late winter/spring weather was significantly correlated with newborn calf to cow ratios. Wolf numbers were significantly correlated with the summer survival of calves. During the wolf control period, caribou on Level Mountain declined by an estimated 11% annually. During the same period, caribou on the Horseranch increased by an estimated 12% annually, with calf recruitment in that period three-four times levels recording before and after wolf reductions.

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1.0 Introduction

1.1 Background

In a review of the status and management of B.C. caribou, Bergerud (1978) noted declines in northern herds. Hunting and predation were identified as the two most likely causes of these declines. Subsequently, several changes were made in caribou hunting seasons, including elimination of cow seasons, shortening of bull seasons, and requiring inspection of all harvested bulls. As well, a research project was initiated to test the role of wolf predation on caribou numbers, particularly on the survival of calves.

This job completion report presents the results of the project. It describes the study areas, the methods used, the data obtained in order to assess the validity of the projects primary hypothesis that reducing wolf numbers will increase recruitment in caribou herds.

1.2 Objectives

In the context of study objectives, two terms used in this report require definition and explanation:

Recruitment - the addition of young animals into a population at some significant time after birth. The recruitment rate is the proportion of a population of a given age or older for one or both sexes, which that given age (and sex) comprises. Three levels of calf recruitment are referred to in this report, including in utero (recruitment into the last trimester of pregnancy); neonatal (recruitment just after calving), and five month recruitment (recruitment into the fall rutting herds).

Herd - a group of caribou that repeatedly use a given area during the calving and rutting season and remain essentially separate from other such groups of caribou during those times. In a statistical sense, herds are also considered to be "populations", each with separate recruitment and mortality rates.

The broad goals in the work reported here were to test the hypothesis that reducing wolf numbers will increase recruitment in caribou herds, to acquire more

information on other factors, e.g. weather, other predators and availability of alternate prey, which might affect recruitment, and to relate these findings to management of wolf-caribou-moose systems in northern British Columbia. The hypothesis was tested by a comparative study of two caribou herds, coexisting with an undisturbed wolf population (Control area) and the other where wolf numbers were experimentally reduced (Removal area). The specific study objectives in retlation to these goals were as follows:

1. to determine t al numbers, sex and age ratios and recruitment rates of both caribou herds.
2. to evaluate the condition, disease status and reproductive performance of caribou on both study areas.
3. to document wolf abundance and distribution on both study areas.
4. to reduce wolf numbers in the removal area by 75 percent.
5. to evaluate the condition, disease status, reproductive performance and food habits of wolves collected in the removal area.
6. to determine moose densities and recruitment rates on both study areas.
7. to document annual movements, distribution and habitat relationships of caribou and moose on both study areas.

2. STUDY AREAS

The study was conducted on two areas, an experimental or removal area (Horseranch Range) where wolf numbers were reduced and a control area (Level Mountain) where no wolf control was undertaken. The study area names refer to the location of calving and rutting grounds in those areas and do not include the annual ranges of the herds. Selection of study areas was ideally based on the following criteria:

1. five month recruitment rate less than 10 percent during surveys in 1977.
2. sufficient number of caribou (200+) present during the fall rut to facilitate surveys and assessment of predator-prey interactions.
3. discrete populations of wolves and caribou present.
4. areas ecologically similar with respect to large mammal fauna, snow regimes, vegetation, physiography and predator-prey ratios.

5. areas logistically feasible for study.

Subsequent analysis showed, however, that conditions 3 and 4 were not well met. While the Horseranch caribou appeared to be a discrete herd, radiotelemetry studies indicated caribou from Level Mountain travelled far outside the study area. Although climatological characteristics at the two areas were similar, local climates and climatic gradients appeared to be very different. The two areas were also topographically dissimiliar with the Horseranch being topographically more diverse as well as climatically more variable (Clements et al. 1983). A brief description of each study area is given below. More information on physiography, geology, geomorphology and soils can be found in Marsh (1980) Clements et al. (1983), and Hamilton (1983). Climatic and vegetation descriptions are provided in Appendix 1.

2.1 Level Mountain

The Level Mountain study area (55° N, 131° W) is located approximately 65 km north of Telegraph Creek in northwestern British Columbia, in wildlife management units 6-22 and 6-26 (Fig. 1). The area, 4560 km^2 in extent, encompasses the shield volcano of Level Mountain and the surrounding lowland. Access is primarily by helicopter, but may also be accomplished by fixed-wing aircraft coupled with hiking or horseback from small lakes (north and west) or "bush strips" (south) in nearby valleys. The nearest road access is the one leading to Telegraph Creek from the Stewart-Cassiar highway at Dease Lake.

The physiography of the area is dominated by the shield volcano of Level Mountain, a low oval-shaped plateau, about 70 km along its long axis, 45 km across and oriented north-south (Clements et al. 1983). Most of the volcano was formed prior to the last glaciation. The older erosional surface of the Nahlin plateau surrounds the volcano at an elevation of 900 m and is composed mainly of acidic bedrock.

The low, gently spring relief of the Level Mountain area is characterized by a relatively uniform climate, with only subtle changes in the local climates below 1670 metres. Annual precipitation is estimated to be about 350 mm with 55% of the total or 190 cm occurring as snow. Above 1700 m, steeper slopes and an improved exposure to local winds tends to clear ridges of snow. During the late May calving

Fig. 1. Location map and place names for the Level Mountain Study Area.

season, average monthly windspeeds are in the order of 3-4 m/sec with mixed rain and snow not uncommon (Marsh 1980).

In the subalpine zone on Level Mountain, subalpine fir forests occupy mesic sites on glacial fluvial, morainal and colluvial materials. Thickets of Betula glandulosa, and Salix shrublands and parkland develop where fires have been frequent. Closed, subalpine fir - lichen forests develop on raised sites in wetland areas; subalpine fir krummholz dot morainal and colluvial blankets. Hydric sites support Carex - willow wetlands. Dense Betula shrub thickets develop on xeric to mesic sites. In the alpine, mesic sites with morainal and colluvial parent materials support dwarf willow and Festuca altaica tundra. Betula glandulosa - Festuca shrub fields occupy xeric to mesic sites with fluvial glacial and morainal parent materials. Seral and climax Kobresia myosuroides tundra develops at low to middle elevations. At higher elevations, similar sites are occupied by seral Carex communities. Sedge - willow wetlands form edaphic climax communities in hydric sites (Hamilton 1983).

The large mammal system includes caribou (Rangifer tarandus caribou), moose (Alces alces andersoni), mountain goat (Oreamnos americanus), Stone sheep (Ovis dalli stonei), wolves (Canis lupus), grizzly bears (Ursus arctos), black bears (Ursus americanus) and wolverines (Gulo gulo). Snowshoe hares (Lepus americanus), beavers (Castor canadensis), ground squirrels (Spermophilus parryii) hoary marmots (Marmota caligata), and three species of ptarmigan (Lagopus spp.) are other potentially important prey in the area. Golden eagles (Aquila chrysaetos) may occasionally kill newborn ungulates.

Two guide outfitters territories and several registered traplines occur in the Level Mountain area, but pressure from both sources is light. Due to difficulty of access, resident hunting is almost non-existent. Since 1977, a compulsory harvest reporting system has existed for caribou, sheep, mountain goats and grizzly bears. Harvests of moose and wolves are unknown, but are probably light.

2.2 Horseranch Range

The Horseranch study area (59° N, 129° W) is located 75 km east of Cassiar in northwestern British Columbia, in wildlife management units 7-52 and 6-23 (Fig. 2). The area, 4000 km^2 in extent, encompasses the Horseranch Range and the

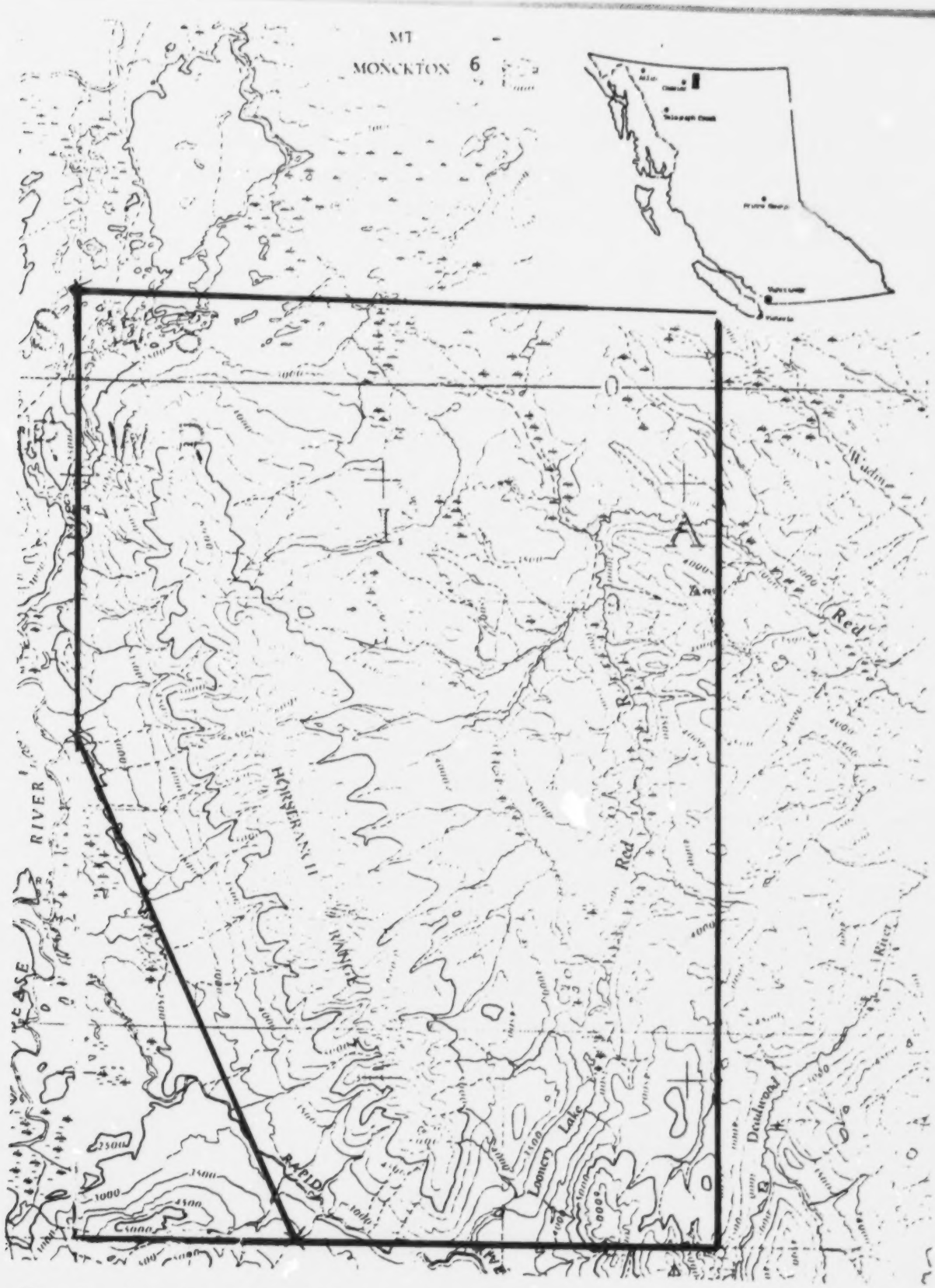


Fig. 2. Location map and place names for the Horseranch Study Area.

surrounding lowland. Access is by floatplane to various lakes or by helicopter. The Stewart-Cassiar road passes 20 km to the west of the study area. The nearest road access is the Beryl Lake road which provides access as far as the west side of the Dease River (Clements et al. 1983).

The Horseranch Range is a sharply defined physiographic unit within the Dease Plateau. The range is 45 km long and 15 km wide with its long axis oriented in a north-northwest direction (Clements et al. 1983). Bedrock in the range is composed of sedimentary gneisses in a doubly plunging anticline whose western front along one valley of the Dease River is a fault (Holland 1963). Steep-walled cirques are found on the eastern side of the range and are occupied in several instances by tarn lakes.

Due to the topographically diverse nature of the Horseranch Range, it is a climatically more variable area than Level Mountain. Annual precipitation is estimated to be 450 mm with 55% of the total or 248 mm occurring as snow. Although greater amounts of snowfall occur on the steeply inclined slopes, higher wind speeds, and the topographically more complex exposure to sun and wind lead to a highly variable distribution of snow cover and a greater variability in snow depths. During late May, wind speeds may average 3.5 m/sec at the lower elevations and 6 m/sec at the higher elevations (Marsh 1980).

The subalpine vegetation of the Horseranch Range is very similar to that in the Level Mountain area. In the alpine, mesic sites in hollows on colluvial and steep rock slopes support Cassiope tetragona and Festuca altaica tundra. Dwarf willow communities occur at higher elevations. Salix - moss shrub tundra occupies mesic to hydric sites on lower receiving slopes. Sedge - willow wetlands prevail in hydric areas. In the middle alpine, seral Dryas integrifolia communities develop on xeric knolls; Potentilla uniflora herb communities predominate at higher elevations (Hamilton 1983).

The large mammal system is composed of caribou, moose, mountain goat, Stone sheep, mule deer (Odocoilcus hemionus), wolves, grizzly bears, black bears, wolverine and lynx (Lynx lynx).

Guide outfitting and trapping occurs throughout the area.

3. STUDY PERIOD

Field work began in September 1977, with the initiation of caribou surveys on both study areas by Bergerud (1978). Intensive studies by the B.C. Fish and Wildlife Branch were initiated in 1978, and continued on both study areas until October 1981. Monitoring continued on the Horseranch study area until 1982. A.T. Bergerud conducted a caribou count on Level Mountain in October, 1982.

4. METHODS

4.1 Data Analysis

In general, the apparent discreteness of the Horseranch caribou range enabled more accurate data to be collected and therefore more detailed analyses to be performed than for the Level Mountain caribou herd.

4.1.1 Formula

Sex and age composition data are expressed both as ratios and as percentages. Sex ratios are reported as males per 100 females and as percent males (adult and yearling males)/(total adults and yearlings). Age ratios are expressed as calves per 100 females, yearlings per 100 females, percent calves (calves/(calves +yearlings + adults)), or percent yearlings (yearlings/(yearlings + adults)).

Rates of increase or population growth are reported in exponential form. The observed rate of increase (r) is calculated as $r=(\ln N_t - \ln N_o)/t$ where N_t is the observed population size in year t, N_o is the population size in the initial year, and t is the number of years. Rates of increase are also reported in percentage form in the text. This is found by taking the antilog_e of r, subtracting 1 and multiplying by 100.

4.1.2 Statistical Analyses

The goal for caribou composition surveys on both areas was total count. Data from the Horseranch were believed to approach that ideal while those from Level Mountain were known not to. In absence of objective data on the actual proportion

of animals observed in either area, the counts from both were treated as samples. This equal treatment enabled comparisons of population parameters with statistical tests.

Statistical procedures follow Zar (1974). Percentage data (0-30% and 70-100%) were first transformed with the arcsin transformation before applying statistical tests. For calf percentages, confidence intervals were based on a normal approximation to the binomial with finite correction factors (Cochrane 1977). Reporting of statistical tests follows the format recommended by Tacha et al. (1982).

4.2 Weather

Since no weather stations existed on either study area, weather data were obtained from the closest possible stations (B.C. Ministry of Environment, Inventory and Engineering Branch) as follows: Level Mountain - snow course stations maintained since 1965 at Dease Lake (4C03, elevation 820 m, 58°26'N, 130°01'N, located 80 km E); Horseranch Range - snow course stations maintained since 1979 at Deadwood River (4C09, elevation 1300 m, 59°15'N, 128°19'W, located within the winter range of the Horseranch caribou). Supplementary information for years prior to 1979 at Horseranch was calculated as composites of data from Cassiar (4C04) and Watson Lake (YK01).

From these stations, a winter severity index (WSI) was developed to express the severity of the spring snowpack on the study areas over the study period. The index expresses the percentage of the April 1 water equivalent (W.E.) of a given year divided by the long-term (15 year) average April W.E. of the site. The rationale for using the April 1 to calculate the W.S.I. was that it may be a measure of difficulty caribou experience in obtaining winter forage under the snow plus a measure of the lateness of exposure and growth of new spring/summer forage. Water equivalent, rather than snowdepth, was used since it was considered to be more representative of the potential for melt and ease of pawing by caribou. The index, however, does not consider either microclimate effects on the study areas in winter or local weather conditions during calving. To evaluate the latter, visual impressions of weather severity during calving were noted on Level Mountain during surveys.

4.3 Wolves

4.3.1 Wolf Removal: 1978-1980

The wolf reduction program was undertaken on the Horseranch study area during March, from 1978-80. All packs recognized as utilizing the study area were subject to the reduction program. Wolf reduction in March 1978 involved the use of toxicants. Poison sites were chosen on the basis of wolf usage. Eleven sites were selected with six to eleven one-wolf dose baits placed at each site. A total of 59 strychnine pellet baits, 9 strychnine eight ounce liver baits, and 32 -sodium monofluoroacetate (1080) baits were placed at those sites. Unused baits were retrieved after two weeks. Kill estimates were obtained by a resurvey of wolf numbers and a comparison with numbers of baits removed. Wolf reduction in March of 1979 and 1980 involved aerial shooting. Two shooters with safety harness worked from each side of the rear of a Bell 206 helicopter. Wolves were shot with 12 gauge shotguns utilizing buckshot.

Whenever possible, wolves were retrieved for necropsy by the Wildlife Research Section, Victoria. Standard morphological measurements, ages, reproductive status of females (in estrus or not in estrus), condition, and disease status were noted. Ages of wolves greater than 1 year were estimated from cementum layers in the canine teeth. Wolves less than 1 year old were identified by tooth development and wear. Condition was assessed from the average kidney fat weight of both kidneys. For adults, kidney fat weights greater than 100 g are indicative of good condition, 45-99 indicates moderate condition and less than 45 g indicates poor condition (Nielson 1977).

4.3.2 Numbers and Distribition

Wolves were inventoried each winter in February or March. Packs refer to groups of wolves travelling together during the survey period. When two or more groups of different sizes were known to have occurred in a particular area, within or between survey periods, the largest number was the listed pack size unless actual sightings of the various groups indicated different wolves were involved. When possible, surveys were flown with a Bell 206 helicopter, preferably on clear days subsequent to a fresh snowfall. Likely wolf travel routes such as river courses, ridges, and meadows were searched for wolf sign. Once found, a trail

was followed until the tracks separated and so could be counted. The latter aspect normally involved several landings and ground inspections. Trails were followed as far as possible in order to identify wolf pack territories.

Wolf activity on the calving grounds was assessed in early June by both opportunistic aerial observations and by traversing the areas on foot and observing scats and tracks of predators. On Level Mountain, summer/autumn use of the caribou range by wolves was evaluated through interviews with hunters, trappers, and government personnel. On the Horseranch Range, wolf numbers on the caribou summer range, were estimated by determining the number of winter wolf pack territories overlapping the summer range. It was therefore assumed that winter territories approximate the summer territories. Wolves, as well as other predators, were also routinely noted during spring and fall caribou composition surveys.

4.3.3 Food Habits

On Level Mountain, summer wolf scats were collected in 1979 from a den-site located on the plateau. R. Page, while studying caribou calf mortality in 1980, also collected and analysed wolf scats for food content. We were unable to find enough wolf scats on the Horseranch Range to analyze summer food habits there.

Winter food habits on Level Mountain were determined by locating and examining wolf feeding sites. Moose and caribou kills were aged by extracting a tooth for incisor sectioning. On the Horseranch, the prey remains in the stomachs and intestines of wolves collected during the removal program were used to assess food habits.

4.4 Caribou

4.4.1 Numbers, Composition and Distribution

Three surveys were undertaken annually during spring, fall and winter.

Spring surveys were conducted by helicopter during calving in June to estimate the sex and age composition of caribou on the calving grounds. On Level Mountain, systematic flights in clockwise direction, and in patterns determined in

flight were used with the objective of a "total count", rather than a sample. Flight speeds and altitudes during searching were 100-125 km/hr at 35-75 m above the ground, depending mostly on local vegetative cover and topography. Once located, animals were observed at close range (20-35 m), usually in a single pass from behind with the helicopter, and were classified to sex and age as follows:

1. Large males (those with antler development sufficient to make them recognizable as males by that feature alone)
2. Small males (animals with little antler development, recognizable primarily by genitalia)
3. Yearling males (very small males, distinguished as such by genitalia and by "long-face"; these were often in company of one or more adult females)
4. Adult females (with calves and/or adults with black vulval patch. These were also classified by presence and development of antlers (one or two hard antlers, no antlers, large (10 cm+) or small (<10 cm) velvet antlers) and udder development (none; present but small; large)
5. Yearling females (small-bodied females (vulval patch present) with long-faces, small velvet antlers and no udder; as with the yearling male, these were often in company of or following older animals)
6. Calves (young-of-the year)
7. Unclassified (adult-size animals not seen well enough to apply the other categories with certainty).

Replicate surveys were conducted in 1978, 1979, and 1980 to evaluate calving chronology. Similar procedures were employed on the Horseranch Range with the following exceptions: (1) a Bell 206 helicopter was flown counterclockwise in concentric contours with the forward observer scanning and marking sightings on a 1:250,000 scale map while the rear observer recorded classification details of each sighting; (2) yearlings were not classified; (3) udder counts were not secured; and (4) calving surveys were not replicated.

Ground surveys on the Level Mountain calving grounds were conducted during a two week period from late May until early June in all years except 1981. On the Horseranch Range, in 1978 and in 1981, much of the caribou calving areas were traversed on foot during the calving period.

Fall surveys were conducted by fixed wing aircraft or helicopter during 1 or 2 days in October, when caribou were assumed to be concentrated on traditional rutting ranges above treeline. On Level Mountain, when group sizes were too large for efficient classification from the air (25 - 30+), the observers were dropped off at preselected ground vantage points. If necessary, the helicopter was used to gently haze the pertinent group past the ground observers who were equipped with binoculars and a 20X spotting scope. Criteria used to distinquish sex and age classes were:

1. Large adult bulls (those bearing a mature complement of antlers, usually including a palmated brow tine ("shovel")
2. Medium adult bulls (those distinguishable as males by antler development, but with smaller antlers and with a simple brow tine)
3. Small adult bulls (males not distinguishable from females by antler development; these were classified as such on the basis of absence of the black vulval patch when viewed from the rear)
4. Adult females (adults with calves and/or the black vulval patch)
5. Calves (young-of-the-year)
6. Unclassified adults (animals which were at least yearlings, but for which sex was not determined)
7. Unclassified (caribou for which no age or sex classification was possible, i.e., none of the previously listed six categories could be applied with certainty)

For the Horseranch, methodology was similar to that used in the June survey. For most years, this count was also utilized for an estimate of total population.

Winter surveys were conducted to determine caribou distribution. Calves were distinguished from adults by body size and short faces. Calves radio-collared by Page (in prep.) on Level Mountain were also relocated to determine if caribou moved outside the study area boundaries. A Telonics programmable scanning receiver was used with two Yagi antennae, one on each wing strut, to first detect, and then move more closely to locate each collared calf.

4.4.2 Calf Recruitment and Survival

In utero recruitment was estimated from: (1) necropsy of 5 adult females from each study area in 1978 to determine pregnancy; and (2) counts of parous adult cows, based on the presence or absence of a distended udder in early June (Bergerud 1964). Pregnancy status could not be determined reliably based on presence or absence of another (Cf. Skoog 1968). On Level Mountain, neonatal recruitment was calculated as calves per 100 adult females on 9-10 June, or just after the peak of calving. On Horseranch, the neonatal recruitment rate was calculated as calves per 100 females in June since yearling females were not classified, and as total number of calves (see 5.3.1.2). Five-month recruitment was measured by the percentage of calves in the herd and calves:100 cows (Horseranch only) during the fall rut survey.

4.5 Moose

4.5.1 Numbers, Composition and Distribution

Moose populations in each study area were estimated by aerial census during mid to late winter. Census boundaries were based on wolf distributions and enclosed at least part of the territory of each major pack in the area. All surveys were conducted in a Bell Jet Ranger helicopter and required 3 to 5 days to complete. Since no standard moose census technology existed for northern B.C. at the time of the study, surveys were conducted differently on each study area as part of a methods development project.

On Level Mountain, moose densities were estimated in 1978, 1979 and 1980 using a stratified random quadrat design (Siniff and Skoog 1964, Evans *et al.* 1966). The study area was gridded into 2.6 km^2 (1 mi^2) quadrats and stratified into three density classes: high (>0.8 moose/km^2), moderate (0.4-0.8 moose/km^2), and low (<0.4 moose/km^2). The classes were based on previous information of moose distribution and habitat characteristics. A nil zone, defined as above 1370 m, was essentially devoid of moose sign. A total of 30 blocks were selected and sampled, providing a 2% coverage of the area. Sampling effort was arbitrarily allocated to 15 high density blocks, 10 medium density quadrats, and 5 low density quadrats. Quadrats were chosen by random draws, with replacement, of numbers from a hat. In practice, it was sometimes necessary to delete a certain quadrat if

excessive ferry time was involved. Another quadrat was then selected. In flight, quadrats were located by finding the nearest identifiable landmark and then proceeding at a constant speed (100 km/h) by compass bearing for a specified time interval. Each quadrat was surveyed by flying four parallel lines, approximately 0.3 km apart, at altitudes from 60 to 150 m. above the ground, depending upon vegetative cover. An attempt was made to count every moose on each quadrat. Tracks were usually of no assistance since 3-4 weeks had often elapsed since the last snowfall. Analysis of the quadrat census data follows the computational procedures outlined by Cochrane (1977) for stratified random sampling. No corrections for visibility bias were made.

Moose densities on the Horseranch study area were estimated in 1979 and 1980 by simple random sampling with unequal size blocks. As with Level Mountain, the area above 1370 m was considered a nil zone and excluded from calculations. Thirty-one polygon shaped blocks ranging from .5 km^2 to 4.5 km^2 were randomly selected and surveyed each year, providing 3% coverage. Boundaries were defined by recognizable landscape features such as gulleys, ridges, and streams. Blocks were searched intensively by flying closely spaced, parallel transects. The census data were first transformed by the square root transformation before computing the average number of moose/km^2 and associated confidence limits. Moose winter distribution was evaluated from the aerial surveys.

4.5.2 Calf Recruitment

During the surveys, moose were classified to age (adult or calf) and, when possible, to sex. Calves were distinguished on the basis of size. For Level Mountain, animals seen between blocks were also classified and included in the age composition analysis. Calf (ten-month) recruitment was measured as the percentage of calves in the winter surveys.

5. RESULTS

5.1 Weather

The April 1 water equivalent (W.E.) and winter severity index (WSI) rating for the two study areas are shown in Table 1. A baseline average snowpack could

Table 1. Winter/spring severity index for the Level Mountain and Horseranch Ranges, 1978-1982.

	Level Mtn.[1]		Horseranch[1]	
Year	April 1 W.E. (mm)	WSI[1]	April 1 W.E. (mm)	WSI[1]
1978	69	48	--	56[3]
1979	188	131	178	117
1980	131	92	159	105
1981	155	108	144	95
1982	222	155	212	140

1 Dease Lake used for Level Mtn., Deadwood River for Horseranch

2 W.E. - Water Equivalent

3 $WSI = \frac{\text{April 1 W.E.}}{\bar{x}(1980+1981)\ \text{W.E.}} \times 100$

not be calculated for the Deadwood site since records were only available since 1979. Examination of other sites in the northern British Columbia, with longer recording histories, shows that 1980 and 1981 were approximately the same as the long term average (e.g. 1965-82 year mean for Dease Lake = 143.4, 1980-81 mean = 143.0). A mean for the 1980 and 1981 W.E. for the Watson Lake - Cassiar composite was therefore used to approximate the long term average. The 1978 Watson Lake - Cassiar composite relative to the 1979-82 Deadwood site matched our perception of that winter's relative snowpack. The WSI ratings for the two study areas were highly correlated ($r=.96$, $df=3$, $.005 < p < .01$) with the WSI lowest in 1978 and highest in 1982. Fig. 3 indicates most of the range in the WSI, as documented since 1965 from Dease Lake, was experienced during the course of the study.

5.2 Wolves

5.2.1 Wolf Removal 1978-80

The location of the 1978 poison sites in the Horseranch area are shown in Fig. 4. The wolf removal program in 1978, 1979 and 1980 reduced wolf numbers by 61%, 86% and 85% of the pre-control levels, respectively (Table 4). Wolves responded rapidly to the reduction, increasing from 14 to 29 in 1979 and 4 to 27 in 1980. The increase in 1979 appeared to result from high pup production and survival although in 1980 it was apparent that immigration played a large role. By 1982, two years after wolf control efforts ceased, wolf densities were as high as pre-control levels.

Standard morphological and condition measurements of wolves collected in 1979 and 1980, when wolves were shot and carcasses retrieved, are shown in Table 2 and Appendix 2. Wolves appeared to be in good condition, based on kidney fat weights. Two wolves had mange. Only one wolf, a 6 year old female was in obviously poor condition. This wolf weighed 40.4 kg and had a kidney fat weight of 28 g. Four of the females autopsied were in estrus. Two females in the Red Pack in 1979 were in estrus, although it was not known if both had been bred. The age distribution of 38 wolves killed during the period is shown in Fig. 5. Pups comprised 32% of the wolf removal and yearlings 27%.

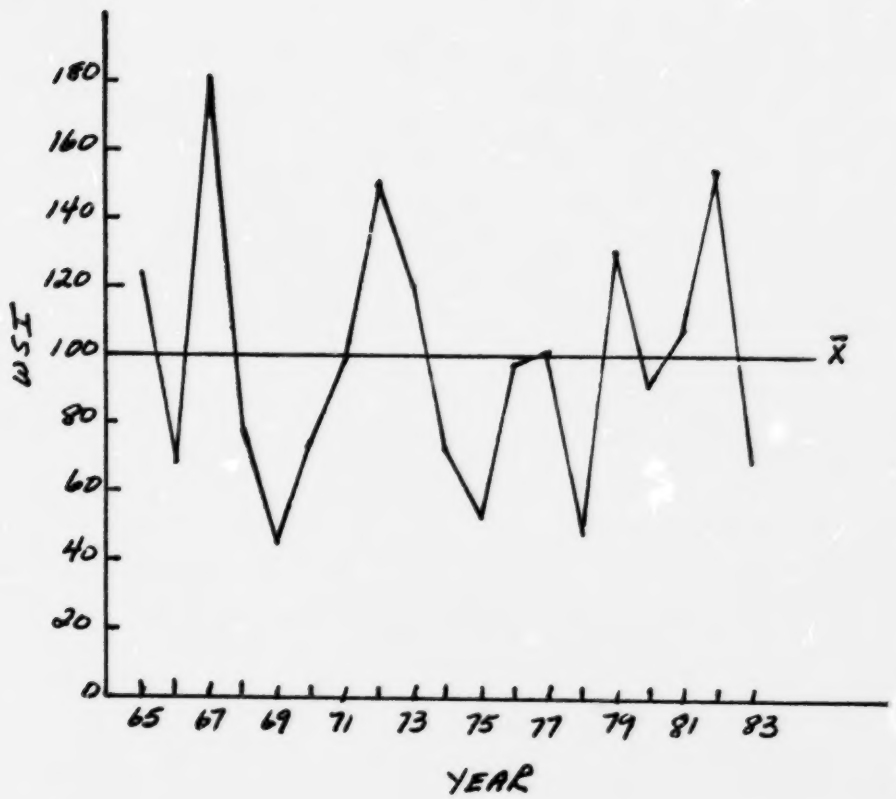


Fig. 3. Winter severity index recorded at Dease Lake, April 1965-83.

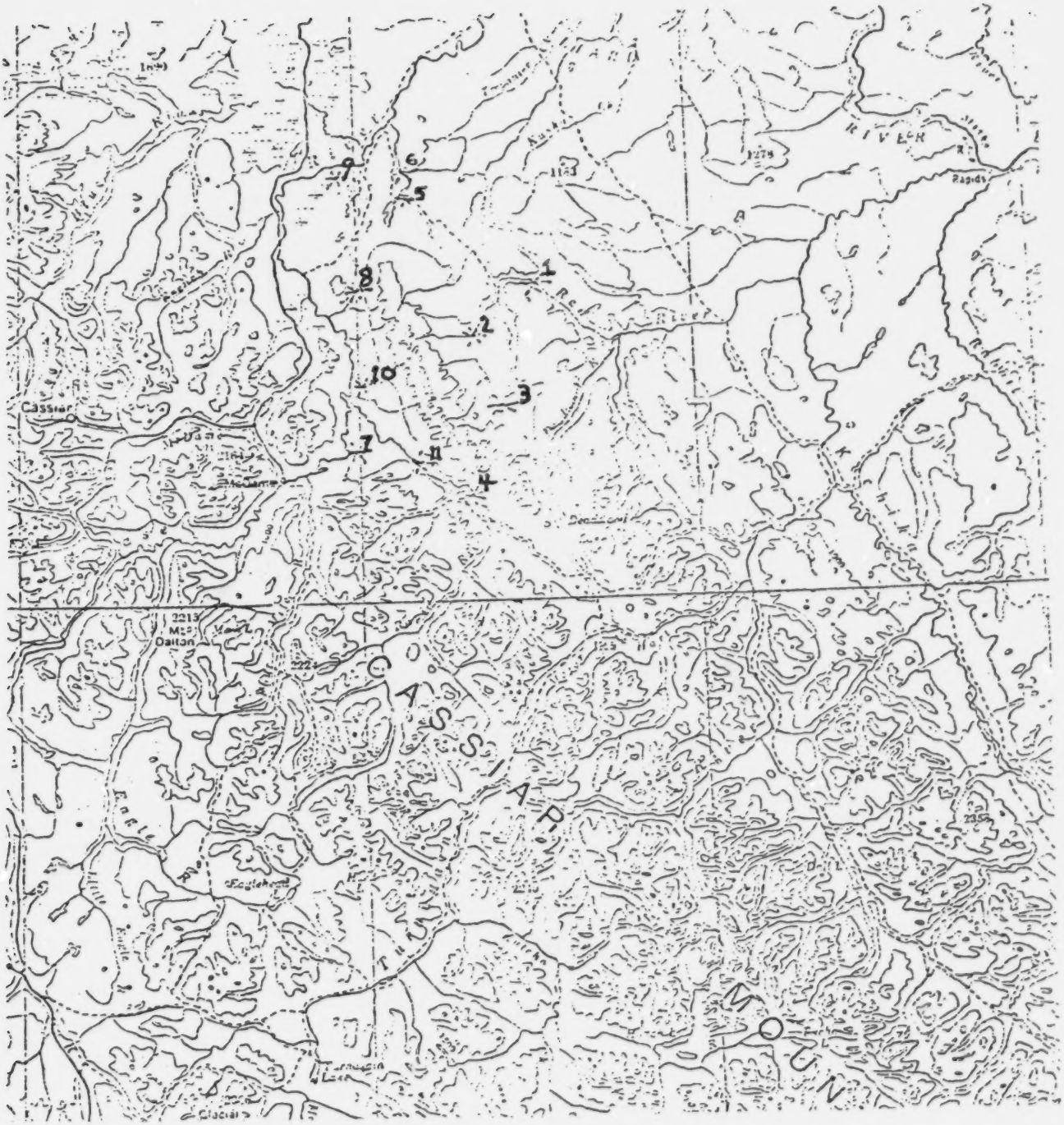


Fig. 4. Wolf poison sites on the Horseranch Study Area, winter 1977-78.

Table 2. Morphological and condition measurements of wolves collected in the Horseranch area, 1979-1980.

Measurement	Adult male			Adult female			Pup		
	$\bar{x}$	(SE[$\bar{x}$])	n	$\bar{x}$	(SE[$\bar{x}$])	n	$\bar{x}$	(SE[$\bar{x}$])	n
Body weight (kg)	49.5	(1.08)	13	41.9	(1.16)	10	33.2	(1.15)	11
Total length (cm)	174.2	(10.31)	13	168.4	(4.24)	10	158.0	(3.07)	11
Neck girth (cm)	51.8	(1.29)	12	50.9	(1.74)	9	42.6	(2.00)	10
Chest girth (cm)	84.5	(2.07)	12	75.9	(2.66)	10	72.4	(1.63)	11
Hind foot length (cm)	28.2	(0.45)	13	27.5	(.31)	10	26.3	(0.41)	11
Tail length (cm)	44.9	(0.96)	12	44.2	(1.46)	10	44.5	(1.18)	11
Kidney fat weight (g)	126.5	(7.53)	12	106.0	(12.66)	10	71.9	(26.03)	7

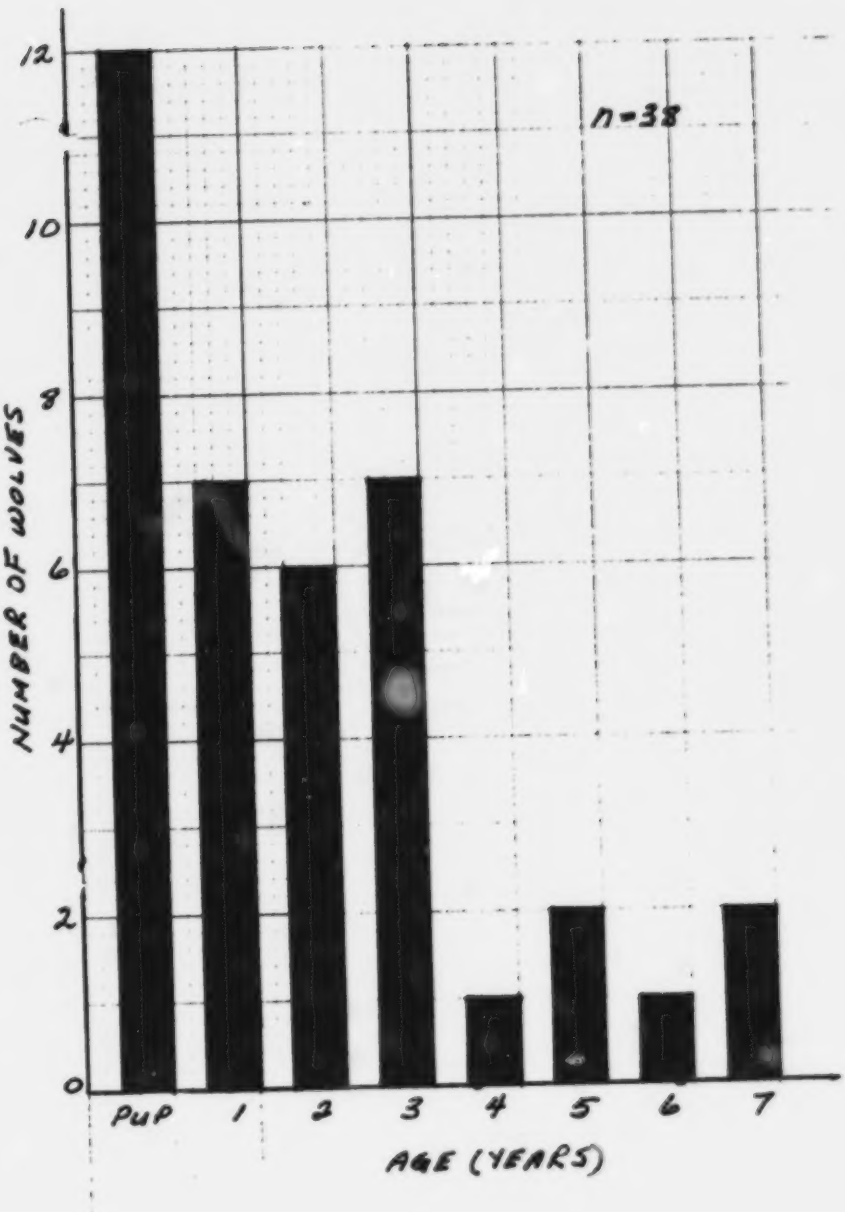


Fig. 5. Age-class distribution of wolves collected on the Horseranch Study Area 1979-80.

5.2.2 Winter Wolf Numbers and Distribution

The identification of packs and their numbers from just a few days observation, primarily from tracks during winter, is difficult and can be misleading (Haber 1978). Since this method was used, our results are subject to some uncertainty. Results were felt to be most reliable when survey flights were made in good light, about 3 days after heavy snow and when adjacent packs showed marked differences in size and colour combination.

On Level Mountain, seven wolf packs were identified in winter (Table 3). All recognizable packs remained fairly well intact, but out limited observations suggest that there may have been fewer singles and pairs on the area in 1981 than in 1978. Insufficient information on movements precluded attempts to identify wolf pack territories.

The number of wolves and wolf packs found in the Horseranch area in late winter from 1978 to 1982 are shown in Table 4. The density estimates are partially artificial since small changes in the area surveyed affects density estimates even when the number of wolves present remains constant. This resulted from the area-searched boundary not corresponding to pack boundaries after 1979. The wolf density estimates are, however, probably indicative of overall wolf abundance. Wolf pack territiories are shown in Fig. 6.

5.2.3. Spring Wolf and Grizzly Bear Activity

On Level Mountain, wolves and grizzly bears were relatively common although few predators were seen on the calving grounds during June. In 1978, predator activity was sparse over most of the upland calving area. Two wolves were observed scavenging on an necropsied caribou carcass and one adult grizzly with 2 cubs was observed on 7 June. In 1979, one wolf den was found in a heavily used calving area. At least 2 adults and 3 pups were present. In 1980, no wolves were observed from the air, although from 4-10 June, 9 different grizzly bears were observed. In 1981 predator activity was once again sparse, with only one grizzly observed on 9 June.

Wolf and grizzly bear use of the Horseranch calving range during the spring appeared to be negligible. In 1978 no recent wolf scats were found during

Table 3. Estimated changes in pack size and total numbers of wolves in the Level Mountain study area, 1978-81.

Pack name	Pack sizes[1]				
	1977-78	1978-79	1979-80[2]	1980-81	mean
Lower Tuya	5	5	6	7-9	6.0
Upper Nahlin	15	12	11+	10+	12.0
Lower Nahlin	13	10+	8-10	13	11.3
Dudidontu	3-5	5	5[3]	5+	4.7
Sheslay	8	5	5[3]	4+	5.7
Tahltan	3+	4-5	6	6-8	5.1
Level Mountain	2+	2	3	1	2.0
TOTAL	49-54+	43-44+	44-46+	46-50+	
Density[4] (km^2/wolf)	89	106	102	96	98

[1] Based on actual sightings and all tracks seen in all winter surveys.

[2] Survey hampered by poor tracking conditions.

[3] Packs not observed in 1979-80 but present in 1980-81, the mean pack size for 1978-79 and 1980-81 was therefore used.

[4] Survey area = 4560 km^2.

Table 4. Estimated changes in pack size and total numbers of wolves on the Horseranch study area, 1978 - 1982.

1978			1979			1980			1981		1982	
Pack[1] name	Pre-control	Post-control	Pack[1] name	Pre-control	Post-control	Pack[1] name	Pre-control	Post-control	Pack name	No.	Pack name	No.
Monckton	11	5	Monckton	9	--	NW	5	0	A	12	A	8
Red	10	8	Red	17	4[2]	W	4+1[3]	0	B	8	B	10
Dease	15	1	Dease	3	--	S	3	1	C	1	D	13
						SE	1	0	D	7	E	4
						NE	13	3			F	3
TOTAL	36	14		29	4		27	4		28		38
Ave. pack size	12.0	4.7		9.7	4.0		5.4	2.0		7.0		5.6
Reduction	61%			86%			85%					
Study area (km^2)	3600			3600			5200			3900		2600
Density (km^2/wolf)	100	257		124	900		193	1300		139		68

1 Including lone wolves
2 Packs no longer recognizable
3 —

Fig. 6. Approximate wolf pack territories in the Horseranch Study Area, 1978-82.

extensive ground traverses over the calving range, nor were any wolves seen from the air. One grizzly sow with cubs was observed from the air but they were feeding on roots. Of the 5 caribou carcasses left on the mountain from the necropsy (1 in rock alpine, 2 in the subalpine and 2 at treeline), none were touched by predators during the two weeks they were watched. In 1981, only 1 wolf and 1 grizzly track were seen during ground studies. Four adult grizzly bears were seen during the aerial survey, but all were at lower elevations than the caribou calves. Wolves were never observed from the air during the calving period. Table 5 presents the number of adult wolves expected to be using the summer range. As with winter wolf numbers, expected summer use declined during the control period and then increased.

5.2.4 Food Habits

Food habits of wolves received limited investigation. For summer, Newall (1978) collected 15 wolf scats on Level Mountain in 1977 and Page (in prep.) analysed scats collected by us from the 1979 wolf den and collected 12 more in summer 1980. The combined results of their analyses showed that the principal prey items were caribou, moose, beaver, and snowshoe hare (Table 6). Adult and unclassifiable caribou comprised 36% frequency of occurrence in the diet, moose 14%, and caribou calves 20%. These results are similar to those reported by Bergerud and Butler (1978) for Spatsizi ($\chi^2 = 2.86$, $df = 2$, $.10 < p < .25$). The importance of calves in the diet, however, was not accurately determined since Newall lumped unidentified caribou remains into the adult caribou category. For consistency it was also necessary to do this with Page's analysis. Because of the difficulty in separating caribou calves from adults in wolf scats, low sample size, biases associated with collecting scats at wolf dens, and because the exact time of scat deposition was unknown, no attempt was made to convert the relative frequencies to the actual proportion of prey items eaten (see Floyd et al. 1978).

For winter on Level Mountain, 25 wolf feeding sites were identified during winter aerial surveys (Table 7). Except for 1 caribou, all feeding sites involved moose. Moose calves comprised 7 out of 20 (35%) of the aged moose remains. None of the adult moose were in the 1-5 age category, seven were aged 6-10 and 3 were greater than 11 years of age. Moose calves and caribou were probably under-represented due to the more complete utilization of these kills which makes them less conspicous. On the Horseranch Study area, moose were also the principal

Table 5. Expected numbers of adult wolves whose territories included the Horseranch caribou summer range, 1972-1982.

Year	No. of wolves	Wolf packs
1978	14	Monckton, Red, Dease
1979	4	Red
1980	1	S
1981	8	B
1982	10	B

[1] Summer caribou range = 1550 km^2.

Table 6. Summer food habits of wolves on Level Mtn. and Spatsizi.

Study area[1]	Frequency of occurrence of prey item (%)					
	Moose %[3]	Caribou[2] %	Caribou Calf %	Other %	N	%
Level Mtn	13.6	35.6	20.3	30.5	59	100
Spatsizi	8.7	53.0	22.1	16.1	149	100

[1] Level Mountain from Page (in prep.), and Newall (1978), Spatsizi from Bergerud and Butler (1978).

[2] Includes adult and unknown caribou remains.

Table 7. Wolf feeding sites on Level Mountain, winter 1978-81.

Date	Location	Prey species	Sex	Age (yr)	Remarks
2 Mar 78	Beatty Creek	Moose	F	6-7	Appears to have fallen through ice, perhaps chased by wolves.
3 Mar 78	Near Tediddech Lk.	Caribou	-	-	Only hair & bone fragments.
4 Mar 78	Tuya Lake	Moose	2M	Large mature	Locked antlers from fall this scavenging.
4 Mar 78	Tuya Lake	Moose	M	10	Skeleton intact*. No blood appears to have frozen before predators found it.
4 Mar 78	Canyon Crk[1]	Moose	-	9	Fairly complete utilization.
26 Mar 78	Granite Lake	Moose	M	Ad.	No jaw.
10 Jan 79	Upper Tuya R.	Moose	F	10	
? Jan 79	Granite Lake	Moose	F	13	Marrow whitish.
10 Jan 79	Nahlin R.	Moose	-	C[1]	This was a calf, but little left.
11 Jan 79	Glundeberry Crk[3]	Moose	M	10	White marrow.
12 Jan 79	Upper Tuya R.	Moose	-	10	Little left.
12 Jan 79	Wille Jack Crk[4]	Moose	-	-	Pink marrow, no head for sex and age.
12 Jan 79	Canyon Creek[2]	Moose	-	13	Little left, but jaw found.
5 Feb 79	Nahlin River	Moose	F	12	Marrow white.
5 Feb 79	Nahlin River	Moose	M	C	Calf of above, both killed within past 3-4 hours.
5 Feb 79	Sheslay R.	Moose	-	-	Only patches of hair and hide left.
80		Moose		C	
80		Moose		U/C	
81		Moose		C	
81		Moose		C	
81		Moose		C	
81		Moose		C	
81		Moose		8	
81		Moose		Ad.	
81		Moose		-	

* Pink Marrow
1 calf
2 NE of study area (Dease Pack?)
3 NW of study area (Kawdy)
4 NW of study area (Kawdy)

winter food item of wolves. Of 19 wolves collected in 1980, all contained moose remains (Table 8). Bergerud and Butler (1978) also reported a predominance of moose (12 out of 16 wolf feeding sites) from Spatsizi.

5.3 Caribou

5.3.1 Calf Recruitment

5.3.1.1 In Utero Recruitment

The in utero recruitment rates for females on both areas was similar to the 86% reported by Bergerud (1979) for 7 North American herds. Of the adult 9 cows collected from the study areas in June 1978, 8 were either pregnant or lactating (Table 9). The weighted percentage of parous females classified on Level Mountain from 1978-81 was 87% (excluding yearlings) and was not significantly different between years (χ^2=7.39, df=3, .05<p<.10, Table 10). Bergerud recommends that parous percentages be reduced by about 5% to compensate for the lack of nonparous females on the calving grounds. Since yearling females rarely breed and adult females produce only 1 calf, in utero recruitment was estimated for both the Horseranch and Level Mountain at 82 calves/100 adult cows.

Antler status could not be used to determine in utero recruitment of caribou, although this method apparently works elsewhere (Skoog 1968). On both study areas, it appeared more common for pregnant females to lose antlers prior to rather than after parturition. For example, on Level Mountain, two females seen in labor in 1978 had both lost their hard antlers. One observed on 1 June, had velvet antler stubs 2-3 cm in length while the other observed on 7 June, had no visible antlers. Two pregnant females collected on Level Mountain in 1978 (4 June and 8 June) had 9 cm and 16-19 cm velvet antlers, respectively. The highest proportion of hard antlered females on Level Mountain, however, was observed near the start of calving. Using all years, the best fit regression between the percentage females with antlers (% AF, arcsin transformation) and survey date (SD) was:

$$\%AF = 42.63 - 2.82\,(SD) \pm 9.90$$

with R^2=.40, F=8.11, df = 1 and 12, and 0.01 <p<0.025. This suggests that 46% of the adult females on average had hard antlers prior to 1 June, although

Table 8. Prey items in stomachs of wolves collected on the Horseranch study area, February 1980.

Prey Item	n[1]	%
Moose	19	100
Beaver	1	5
Snowshoe hare	1	5

[1] No. of stomachs having food items, total number of stomachs examined = 19.

Table 9. Reproductive status of female caribou collected on Level Mountain and Horseranch Range, June 1978.

Sample	Level Mountain status	Horseranch Range status
1	n/a (calf)	pregnant
2	pregnant	lactating
3	lactating	lactating
4	pregnant	pregnant
5	barren	pregnant

Table 10. The percentage of parous adult females classified during the calving seasons on Level Mtn. during June 9-10, 1978-81.

Year	Proportion parous	n	Proportion of cows at least with 1 hard antler	(n)
1978	89%	(37)	0%	(37)
1979	78%	(68)	7%	(68)
1980	92%	(39)	5%	(40)
1981	93%	(44)	16%	(44)
All years	87%	(188)	7%	(189)

approximately 87% were pregnant. Bergerud (1981) also noted that some pregnant females may shed their antlers several weeks before calving, while some nonparous females may continue to carry hard antlers until June.

There was some indication that the antler cycle was related to the female's nutritional status, as reflected by spring weather severity. On Level Mountain, no antlered females were observed in 1978, an exceptionally mild spring, whereas in other years where spring severity was near average or above average, 5-16 percent of the females still had hard antlers. This was also supported by antler chronology (Fig. 7). By introducing a dummy variable for below average (0) or average (1) snowpack, the regression of percentage adult females with one hard antler on survey date was significantly improved. The resulting best fit equation (arcsin transformation) was:

$$\%AF = 29.40 - 3.13(SD) + 19.34 \text{ (snowpack rating)} \pm 5.27$$

with $R^2 = .85$, $F = 29.98$, $df = 2$ and 11, and $p < .0005$. This suggests that antler drop and possibly calving were more advanced or contracted during milder springs. Similar results were also found on the Horseranch. In 1978, 27-42% of the females had advanced antler development, with many of these females being pregnant. In 1979, under more severe conditions, only 19-33% had advanced antler development.

5.3.1.2 Neonatal Recruitment

On Level Mountain, replicate calving surveys were conducted in 1978, 1979, and 1980. The general survey route flown each year is shown in Appendix 3. Most of the calving appeared to occur above treeline, although on 1979 June 10 a cow and calf were observed below treeline at 1100 m. The calving chronology during 1979 and 1980 is shown in Fig. 8. The best fit equation for 1980 between calves: 100 adult cows (CC) and survey date (SD) was:

$$CC = -16.26 + 19.63 (SD) - 0.97 (SD)^2 \pm 16.94.$$

with $R^2 = .72$, $F = 5.16$, $df = 2$ and 4, and $0.05 < p < 0.10$. The best fit equation for 1979 was:

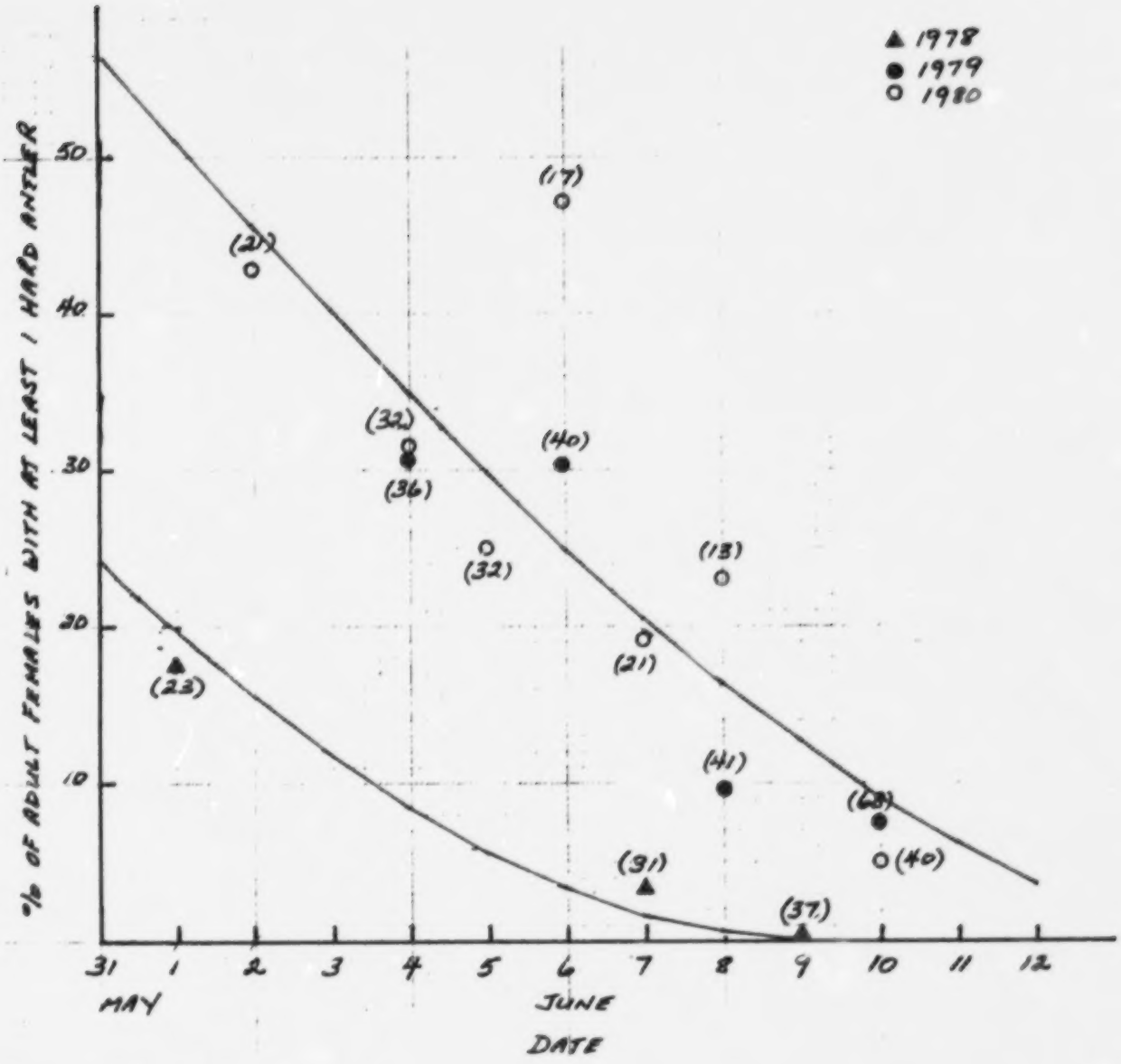


Fig. 7. Percentage of adult females with at least one hard antler observed during the calving period, Level Mtn. 1978-80 (see text).

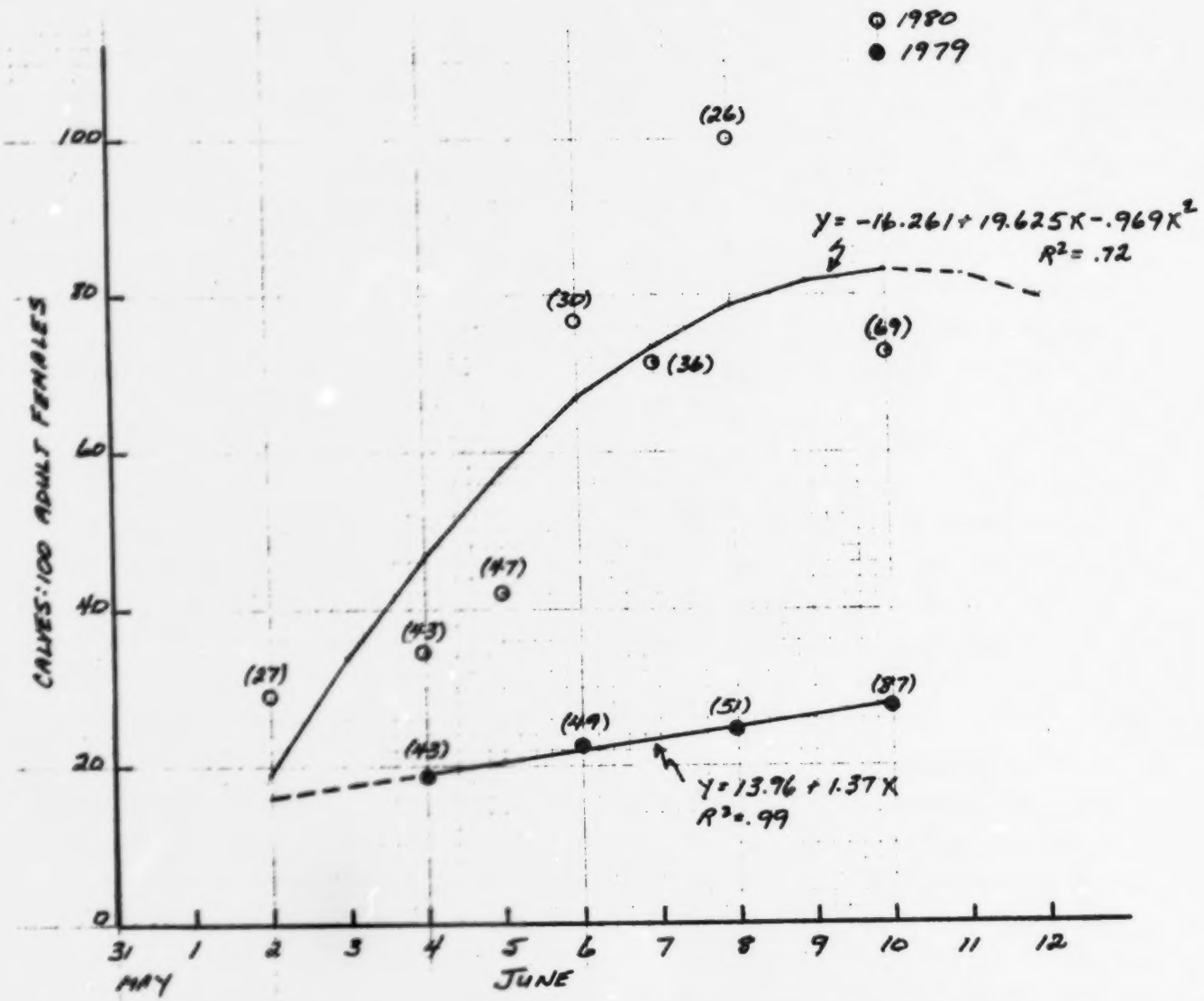


Fig. 8. The calving chronology on Level Mtn. during a relatively mild and severe (1979) spring. Sample size is shown in parentheses.

$CC = 13.96 \pm 1.37 (SD) \pm 0.47$

with $R^2 = .99$, $F = 173.79$, df=1 and 2, and $.005 < p < .01$. Based on the regression curve for 1980, the peak of calving was about June 10, and the neonatal recruitment rate about 83 calves per 100 adult cows, or similar to the in utero rate. To standardize estimates of annual neonatal recruitment, survey results fom the June 9-10 period were used (Table 11).

Neonatal recruitment rates could be biased if many calves were born after June 10 or calves were less visible than adults. Although some calves were probably born later, the synchronous nature of caribou calving (Bergerud 1974) suggests few calves are born late and that such calves experience a higher neonatal mortality rate. Survey results on 1980 June 10 indicated in utero recruitment (82 calves:100 cows) and neonatal reruitment (73 calves:100 cows) were similar, which suggests most calves that year were born live, and that there was little differential visibility bias against calves. We assumed a similar pattern for several years. A strong visibility bias against seeing caribou, however, was apparent during this survey. Of 16 live radio-collared calves present on the plateau during the survey, only 5 of the 29 calves (17%) observed wore collars. At 73 calves/100 cows, a simple Lincoln index suggests 93 calves and 128 cows could have been present, or 3.2 times the number of calves and cows observed.

Calving surveys were conducted about 10 days later (16-25 June) on the Horseranch Range. The survey route flown during June is shown in Appendix 5. Females with calves tended to be in the rougher alpine on the mountain where visibility was excellent, although a few were observed at treeline where visibility was lower. Only bulls and cows without calves were seen in the timber, where visibility was lowest. Thus, a greater proportion of cows than calves were probably missed. Although it was not possible to measure the proportion of spring calves or cows seen, it was felt, based on the observed distribution relative to treeline, that on the order of 90% of the calves were observed. The proportion of cows missed was unknown but since the number of cows seen in October was similar among years (Table 14), it may be a close approximation to the number present in June. If this is true, then 39-91% of the Horseranch cows were observed during the June surveys. Consequently, we used total numbers of calves rather than calf:cow ratios (Table 12) as the best estimate of neonatal recruitment.

Table 11. Estimated composition of caribou on Level Mtn. near the end of the calving season[1] in 1978-1981, based on aerial surveys.

Year	Total Caribou	Bulls				Cows				Calves				Yearlings	
		Adults		Yearlings		Adults		Yearlings							
		No.	(%)[2]	No.	(%)[2]	No.	(%)[2]	No.	(%)[2]	No.	(%)[3]	per 100[4]	per 100[5]	No.	(%)[2]
1978	113	50	(53)	4	(4)	37	(39)	4	(4)	18	(16)	49	44	8	(8)
1979	132	29	(26)	9	(8)	68	(60)	7	(6)	19	(14)	28	25	16	(14)
1980	113	29	(35)	12	(14)	40	(48)	3	(4)	29	(26)	73	67	15	(18)
1981	99	17	(21)	14	(17)	44	(54)	7	(9)	17	(17)	39	33	21	(26)

1 9 June 1978, 10 June 1979, 10 June 1980, 9 June 1981.
2 % among adults and yearlings
3 % of total caribou classified
4 calves per 100 adult cows
5 calves per 100 cows (includes yearlings).

Table 12. Estimated composition of caribou on the Horseranch Range near the end of the calving season[1] in four consecutive years from 1978-82, based on aerial surveys.

Year	Total caribou	Bulls		Cows		Calves		
		No.	(%)[2]	No.	(%)[2]	No.	(%)[3]	per 100[4]
1978	256	18	10	158	90	80	31	51
1979	240	21	11	170	89	49	20	29
1980	175	30	23	98	77	47	27	48
1981	221	56	31	123	69	42	19	34
1982	125	23	22	81	78	21	17	26

[1] 16 June 1978, 21-25 June 1979, 18 June 1980, 25 June 1981, __ June 1982.
[2] % among adults and yearlings
[3] % of total caribou classified
[4] calves per 100 females (includes yearlings).

Table 13. Composition of fall survey samples at Level Mountain, 1977 - 1982.

Date	Total[2] caribou	Large bulls[3] No.	Large bulls[3] (%)[4]	Calves No.	Calves (%)
26 Sept. 1977[1]	434	77	(20)	16	(4)
10 Oct. 1977	228	38	(18)	13	(6)
11 Oct. 1978	229	21	(12)	57	(25)
21 Oct. 1979	286	44[5]	(17)	27	(9)
27 Sept. 1980	184	9	(6)	30	(16)
13 Oct. 1981	108	15	(15)	7	(6)
Oct. 1982[6]	129	-	-	1	(1)

1 classification by Bergerud (1978).

2 number seen and classified to at least adult or young-of-the-year (calves).

3 mostly males recognizable as such by antler and pelage characteristics, i.e., large and medium as defined earlier.

4 Per cent of number classified among adults, i.e., not including calves.

5 This is the total number of males recorded in that year, but ony 3 are actually listed as large; the 44 is valid as a comparative figure only <u>if</u> these animals were recognized as males by antlers and pelage rather than by genitalia.

6 classification by A.T. Bergerud and B. van Drimmelin.

Table 14. Composition of all fall survey samples at Horseranch Range, 1977 - 1982.

Date	Total caribou[1]	Bulls		Cows		Calves		
		no.	(%)[2]	no.	(%)[2]	no.	(%)[3]	per 100 cows
1977[4]	237	-	-	-	-	15	(6)	
1978	263	37	(17)	182	(83)	44	(17)	24
1979	274	40	(18)	187	(82)	47	(17)	25
1980	311	78	(30)	183	(70)	50	(16)	27
1981	329	97	(33)	196	(67)	36	(11)	18
1982	337	115	(36)	208	(64)	14	(4)	7

1 all caribou seen were classified to adult or yearling male, adult or yearling female, and calf.

2 per cent of number classified among yearlings and adults, i.e., not including calves.

3 per cent of total caribou seen.

4 classification by Bergerud (1978).

Table 15. Calculation for estimating Horseranch caribou composition, October, 1981 (see text).

OBSERVED

	adult	calf	total	% calves
above treeline	121	25	146	17.1
below treeline	98	6	104	5.8
all locations	219	31	250	12.4

EXPECTED

	adult	calf	total	% calves
above treeline	121	25	146	17.1
below treeline	172[1]	10[2]	182	5.8
all locations	293	35	328	10.7

[1] midpoint of 1980 and 1982 total adult numbers = 293. 293-121 adults above treeline = 172 adults below treeline.

[2] .058 x 172 = 10 calves, assuming 5.8% of the animals below treeline are calves.

With the exception of 1980, on Level Mountain, neonatal recruitment was substantially lower than in utero recruitment on both study areas. This suggests that considerable mortality occurred just before or shortly after birth. Due to the different biases operating on both study areas it is difficult to compare recruitment rates. The best comparison appears to be that of total calves on the Horseranch with calves/100 adult cows on Level Moutnain. The two are poorly correlated ($r=.06$, $df=2$, $p>.50$). Much of the discrepancy, however, appears to be due to the high estimated recruitment rate on Level Mountain in 1980.

5.3.1.2.1 Effects of Weather

On Level Mountain, neonatal recruitment was poorly associated with the WSI ($F=0.58$, $df=1$ and 2, $p>.50$). As indicated in Fig. 9 the poor relationship can primarily be attributed to recruitment in 1980. The high recruitment rate could have been a result of unprecendently mild weather conditions during calving. Our notes indicate almost no measurable precipitation occurred between 2 and 10 June with 5-10 June being a series of extremely clear, hot days with temperatures peaking near 27° C, even at elevations above 1800 m. This suggests that the extremely favourable conditions during calving may have mediated some of the effects imposed by spring weather conditions on neontal viability.

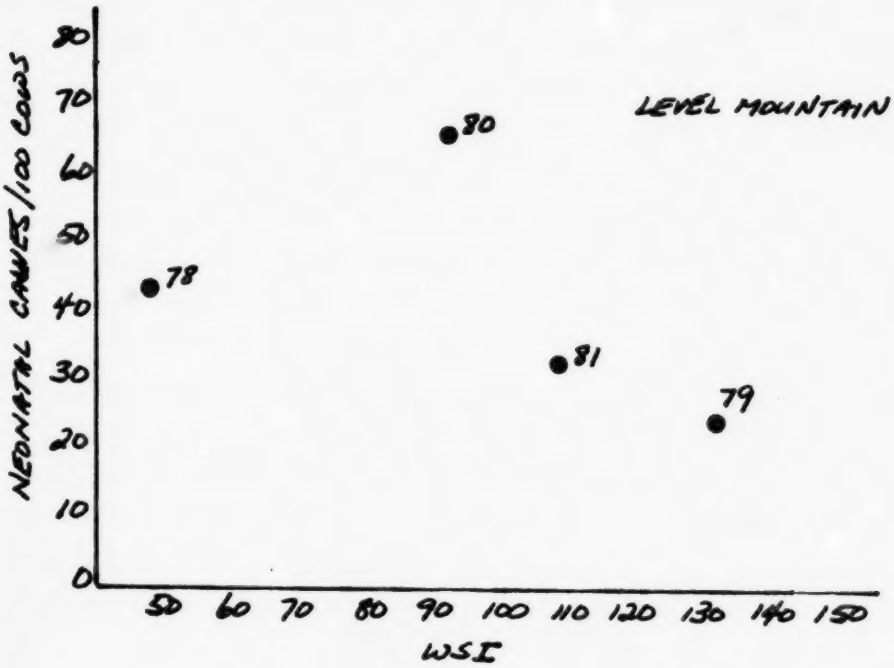
On the Horseranch Range, a significant relationship existed between the WSI and neonatal calf numbers. The best fit linear equation between calf numbers (NC) and the WSI was:

$$NC=113.06-0.64\ (WSI) \pm 8.88$$

with $R^2=.87$ and $F=19.71$, $df=1$ and 3, and $.01 < p < .025$ (Fig. 9).

5.3.1.2.2 Effects of Predation

On Level Mountain, predators were not particularly conspicuous on the caribou calving areas. However, one wolf den was located in a heavily used calving area in 1979, the year of lowest neonatal recruitment (28 calves:100 cows), but also following a relatively severe winter. In 1980, when Page conducted his study of caribou calf mortality, he observed little wolf activity on the calving grounds and only two losses (non-predator) occurred prior to 10 June (Table 16). The highest



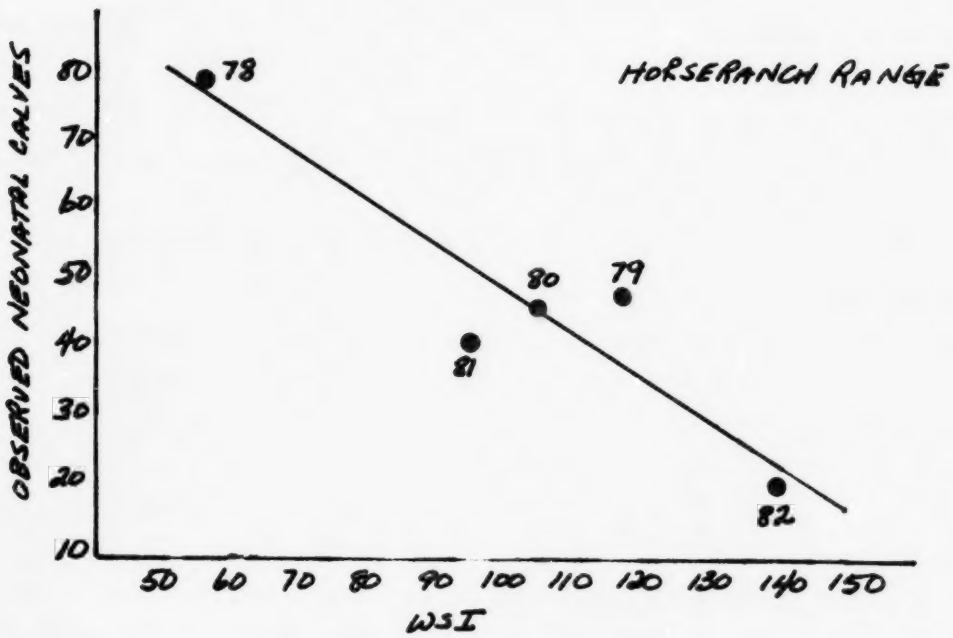


Fig. 9. Relationship between neonatal recruitment and the winter severity index (WSI).

neonatal recruitment (73 calves:100 cows) for the study period was also recorded. However, winter severity was average in 1980 and, as previously mentioned, calving weather was exceptionally favourable.

On the Horseranch, there was no indication that neonatal recruitment was related to predation. Both wolf and bear activity on the calving areas were minimal. Summer wolf numbers were not correlated with spring calf numbers ($r=-.45$, $df=3$, $0.20<p<.50$).

5.3.1.3 Five Month Recruitment

On Level Mountain, virtually the entire plateau was surveyed each fall. Appendix 4 shows the survey route flown in 1981. Despite the intensive coverage, only a sample of the population was classified, although the 1977 September count by Bergerud (1978) may have been close to a total population enumeration (n=441). On the Horseranch, the same survey route flown in June was also flown in October. In all cases, almost the entire area above treeline was searched, as well as varying amounts below (Appendix 5). In 1981, poor weather conditions delayed the survey by ten days. By then many of the caribou had moved from the alpine onto low elevation timbered winter ranges. With the exception of that year, most of the herd was thought to be classified.

On Level Mountain, 5 month recruitment (% calves) was low in 1977, 1979, 1981 and 1982 and high in 1978 and 1980 (Table 13). Even considering confidence limits for calf percentages, the fluctuations are still apparent (Fig. 10). Part of the alternating pattern between low and high recruitment observed from 1977 to 1981 may be explained by the proportion of non-breeding yearlings following years of high recruitment. However, this effect would be less than the magnitude of the fluctuations observed.

Five month recruitment (% calves and calves:100 cows) for the Horseranch Range are shown in Table 14 and Fig. 10. In 1981, because many of the caribou had already moved onto the winter range, a complete count was not possible, nor was it feasible to identify the sex of the adult animals. In consequence, estimated total adult numbers were calculated as the midpoint between the 1980 and 1982 levels. Calf numbers were then extrapolated from the proportion of calves below treeline times the number of adults expected below treeline, plus the number of

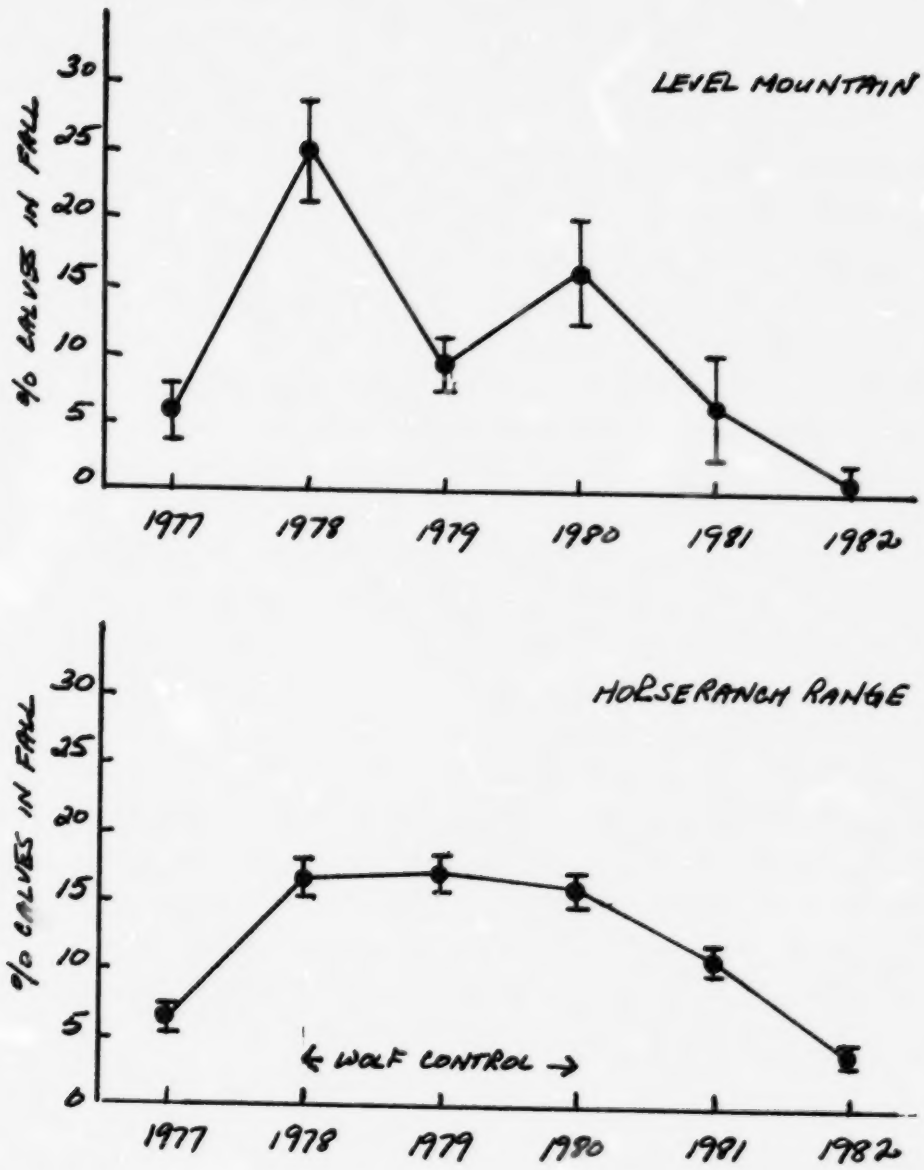


Fig. 10 Fall calf percentages on Level Mountain and Horseranch Range, 1977-82. Finite correction factor applied to calf percentages, assuming Level Mountain herd $\leq$ 500, and 90% of Horseranch herd observed.

calves above treeline. This assumed all caribou above treeline were observed (Table 15). Calves:100 cows and % calves were significantly correlated C arcsin transformation: r=.99, df=3, .001<p<.0025).

Estimating five month recruitment proved difficult for the Level Mountain herd. For example, although the percentage of yearlings in spring increased from 1978 to 1981 while the overall trend in fall calf percentages decreased from 1978 to 1982. While the actual number of yearlings observed was always less than the number of fall calves the previous year, yearlings:100 cows exceeded calves:100 cows in 3 out of 4 years. Since caribou calves die at greater rates than adults during their first winter of life (Bergerud 1980), either the fall and spring counts were not sampling the same population, or one or both recruitment estimates were biased. Spatsizi caribou studies have shown that cows with calves may be less likely to join rutting groups, thus may often be missed on the fall counts (Hatler 1983). It is doubtful, however, that these factors could fully explain the extremely low fall calf percentage in 1982.

5.3.1.3.1 Effects of Weather

Although summer forage production is affected by precipitation and temperature, there was no reason to suspect that weather was limiting summer forage production and thus influencing five month recruitment. Other North American studies have also not postulated summer weather as a potential limiting factor on caribou recruitment (Bergerud 1979).

5.3.1.3.2 Effects of Predation

On Level Mountain, the lack of information on summer wolf densities did ot enable an analysis of the relationship between five month recruitment and wolf densities. Consequently, the impact of predation on recruitment could only be assessed for 1980 when Page conducted his calf mortality study. All of the mortalities after the June 10th period were known or suspected to be due to predation, 6 to wolves and 3 to grizzly bears (Table 16). The summer survival rate, based on the radio collared sample, was 52%; 82% of the total mortality was attributed to predation. Our subjective impressions of wolf activity that summer suggested that 1980 was typical for wolf activity on the plateau, although more

Table 16. Summary of mortality causes among 23 radio-collared caribou calves on Level Mtn. 1980 (from Page, in prep.).

	Number of Dead calves	% of Total calves that died
Predation - Excluded Losses		
Probable Aneurism	1	9
Probable Drowning	1	9
Subtotal	2	18
Predation - Involved Losses		
Wolf	6	55
Definite	1	9
Probable	1	9
Possible	4	36
Grizzly Bear	3	27
Definite	2	18
Possible	1	9
Subtotal	9	82

grizzly sign was present. Page (pers. comm.) considered the predator activity to be much less than that for Spatsizi in 1979.

On the Horseranch Range, fall calf percentages and calf:cow ratios increased during the period of wolf control, and declined after control was terminated (Fig. 10). To assess the effect of wolf predation on 5 month recruitment, the relationship between the number of wolves expected on the caribou summer range and summer calf survival was examined. Since calf survival cannot be less than zero percent, and wolf numbers could theoretically be considerably above those found, a logarithmic transformation was used to obtain a best fit linear regression between summer calf survival (SS) and wolf numbers (W) as follows:

$$SS=116.71e^{-0.05(W)}\pm 6.07$$

with $R^2=.94$, $F=51.021$, df=1 and 3, $.005<p<.01$ (Fig. 11). The 1980 data point is obviously in error since calf survival can not exceed 100%. However, the trend between calf survival and wolf numbers is believed to be correct. It indicates that as wolf numbers increase, the summer survival of calves decreases.

5.3.1.4 Population Size and Trends

Annual survey totals (population estimates) for Level Mountain and the Horseranch from 1977 to 1982 are shown in Fig. 12. On Level Mountain, using the baseline count obtained by Bergerud (1978) in September 1977, caribou declined at an annual rate of 22% (r=-.24). Using the baseline count of 228 by us in October 1977, the annual rate of decline was 11% (r=-.11). On the Horseranch Range, caribou increased at 7% annually (r=.07) since 1977. Rates of increase were 12% annually (r=.11) during the control period; and 4% annually (r=.04) during the post-control period, which includes one year (1982) of intermediate wolf numbers and one year (1982) of near normal wolf numbers (Table 5).

It is doubtful that the Level Mountain figures are accurate. The one year of replicate surveys (1977) showed an almost two-fold difference in total caribou enumerated. The observed rate of decline also seems too severe based on five month recruitment estimated adult mortality of 4-13% and 5% hunter harvest (Appendix 6). At least part of the observed decline is suspected to be due to emigration and/or to some animals being missed during the surveys. For example,

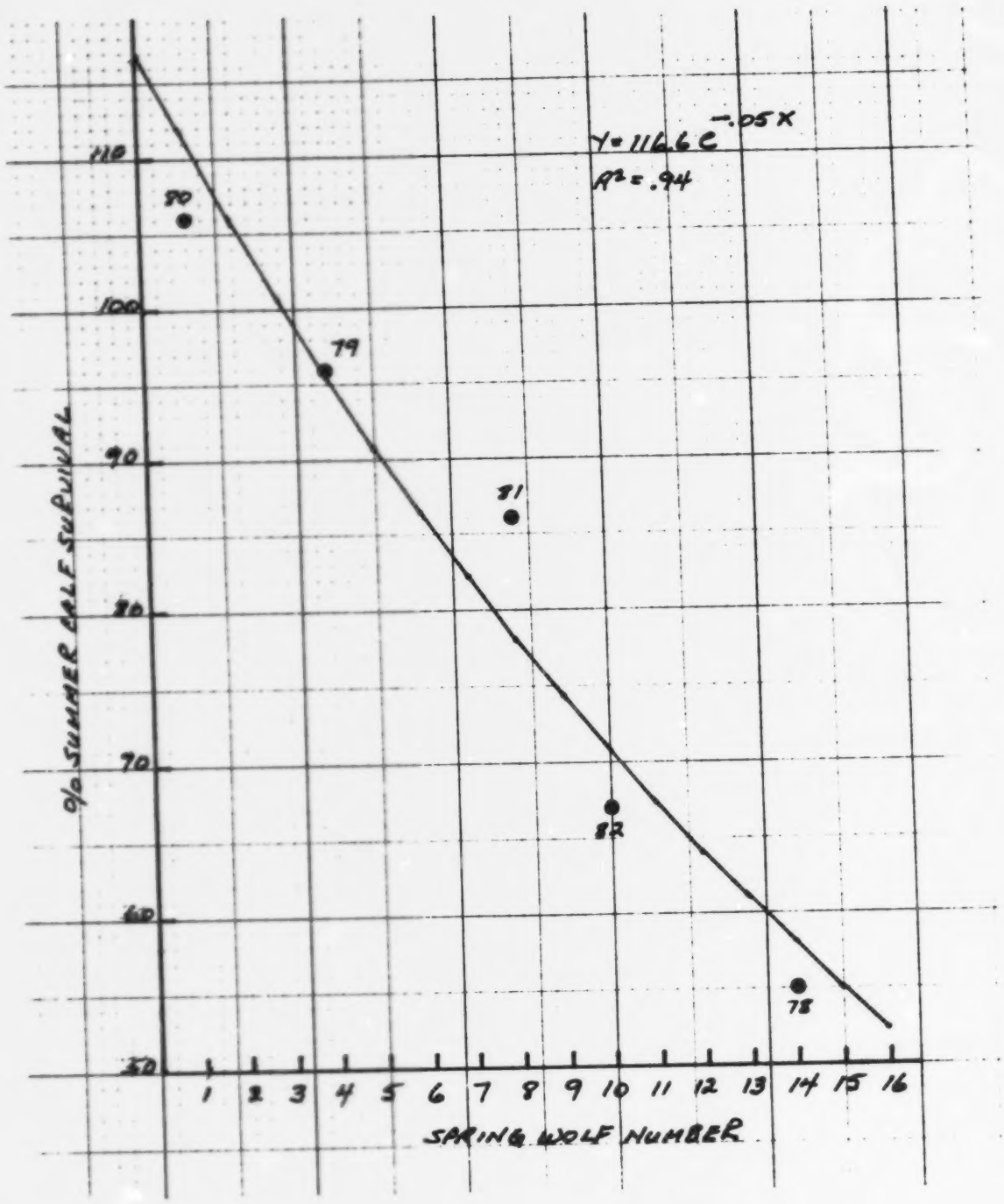


Fig. 11. Relation between apparent summer caribou calf survival and spring adult wolf numbers on the Horseranch Range.

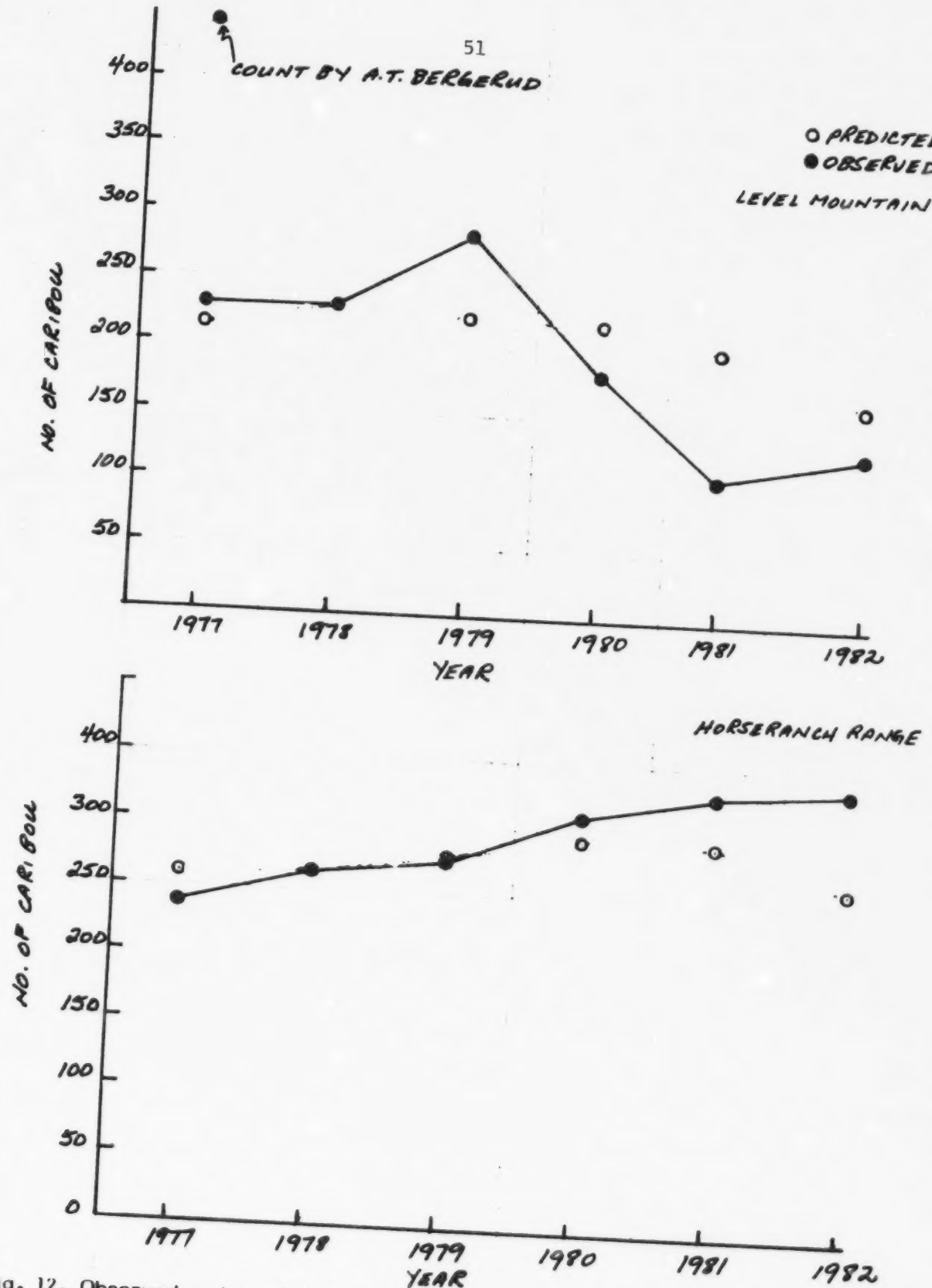


Fig. 12. Observed and predicted caribou population trends at Level Mountain and Horseranch Range, 1977-82.

on 31 July 1978, 300-350 caribou were observed together on a single snow patch on the north side of Level Mountain, although the fall count two months later yielded only 229 animals. On 27 September 1980, only 3 of 6 radio-collared calves known to be present were seen among 184 animals observed. Thus it is possible that 50% of the population could have been missed during some surveys. However, it is still likely that the Level Mountain herd declined during the study period. The Horseranch estimates, due to the discreteness of the caribou range, are believed to be more accurate, and the calculated rates of increase more reliable (Appendix 7).

5.3.1.5 Annual Movements, Distribution and Habitat Relationships.

Only limited information on these aspects of caribou biology were collected during the study. An examination of habitat relationships is in preparation.

On Level Mountain, calves were born at all elevations between at least 1400 m and 2000 m. The higher elevations appeared to be used in preference if winter snowpack has receded sufficiently to allow it (Table 17). The animals were fairly well dispersed during the main calving period (end of May through 10 June), but began to gather into larger groups in the second half of June. There was some evidence that the early aggregations were heavy to bulls, yearlings, barren cows and cows which had lost calves; maternity bands (1-6 cows with calves) remained separate for a time, mostly at higher elevations. Generally it appeared that the animals spent the summer in the Level Mountain Range and on the surrounding plateau, mostly above 1700 m. By late fall, and rut time, most had gravitated to the northeast side of the plateau.

After the rut, probably depending upon the timing and extent of snowfalls, the caribou moved off the plateau. Tracks and limited observations suggested that most of the movement was probably off the north side. At least some appeared to winter in the Nahlin - Tachilta Valley to the north, although the origin of animals seen there cannot be ascribed with certainty. Radio-telemetry locations of calves tagged by Page, in winter 1980-81, indicated extensive movements outside the study area (Fig. 13). On 16 January 1981, two calves were located over 80 km away from the study area. Another flight on 16 February 1981 located two other calves in the Teslin - Jennings area. Some, and possibly most of the herd had therefore travelled north and west from the Nahlin - Tachilta Valley to winter 80 - 110 km from the northwest edge of the study area. The animals moved back onto

Table 17. Elevation of caribou groups on Level Mountain (in m) observed in June during a mild (1980) and severe (1981) calving season.

	Elevation of Groups with Calves			Elevation of Groups without Calves			Elevation of all Groups Combined		
Year	$\bar{x}$	(SE[$\bar{x}$])	n	$\bar{x}$	(SE[$\bar{x}$])	n	$\bar{x}$	(SE[$\bar{x}$])	n
10 June 1980	1703	44.7	16	1596	31.7	14	1653	29.3	30
9 June 1981	1533	47.3	13	1488	29.3	21	1505	25.4	34

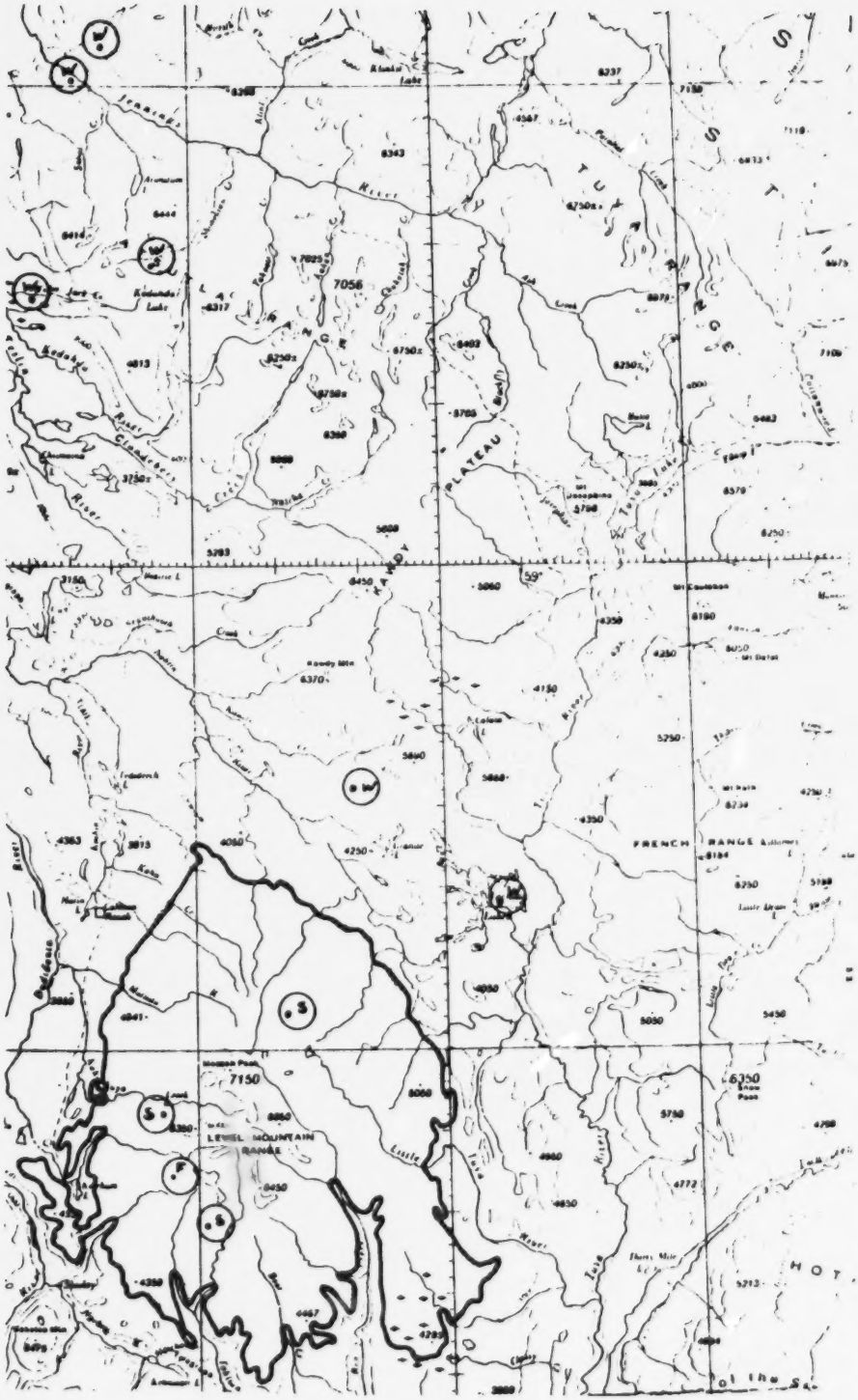


Fig. 13. Winter locations of caribou calves radio-collared at Level Mountain. (W=winter location, F=fall location, S=summer location).

Level Mountain beginning in late May and early June. During the years of this study, most appearances were from the southwest and west. Since little caribou sign was found in winter in the Dudidontu Valley (west of Level Mountain), it appears that the animals moved through there, from north to south, in April or May. In all years a few animals appeared on the mountain from the north side, apparently coming up from the Nahlin - Tachilta Valley. Much of the habitat utilization on Level Moutnain above 1500 m in early spring was associated with the Kobresia vegetation landscape although other vegetation landscapes were also used (Appendix 8).

On the Horseranch Range, most of the calving and probably all of the rutting occurred above treeline. Due to the isolated nature of the area, caribou movements appeared to be less extensive than for Level Mountain. However, no radiotelemetry studies on movements have been done. Winter distribution during the study period is shown in Fig. 14. Much of the habitat utilization on the Horseranch Range, above 1500 m in early spring, was associated with the willow-moss vegetation landscape.

5.4 Moose

5.4.1 Calf Recruitment

Winter (8 month) moose calf recruitment on the Level Mountain study area ranged from 14 to 28% of total moose seen (Table 18). Although percentages were generally lower at higher wolf densities, the relationship was not statistically significant ($F=4.28$, $df=1$ and 2, $.10<p<.25$) (Fig. 15). Calf recruitment on the Horseranch area increased from 9% in 1979 to 13% in 1980, also coincident with a reduction in wolf density, but it must be noted that sample sizes were small (Table 18, Fig. 15).

Spring (12 month) calf recruitment can be estimated for the Level Mountain population, assuming 0.7 moose are killed per wolf per month during winter and that wolves kill calves at about twice their abundance in the population during late winter (Appendix 14). Based on these assumptions, estimated recruitment rates were: 1979-20%, 1980-25%, and 1981-14%. These changes in rates represent a 10-15% decline in the numbers of moose calves between the ages of 8 and 12 months.

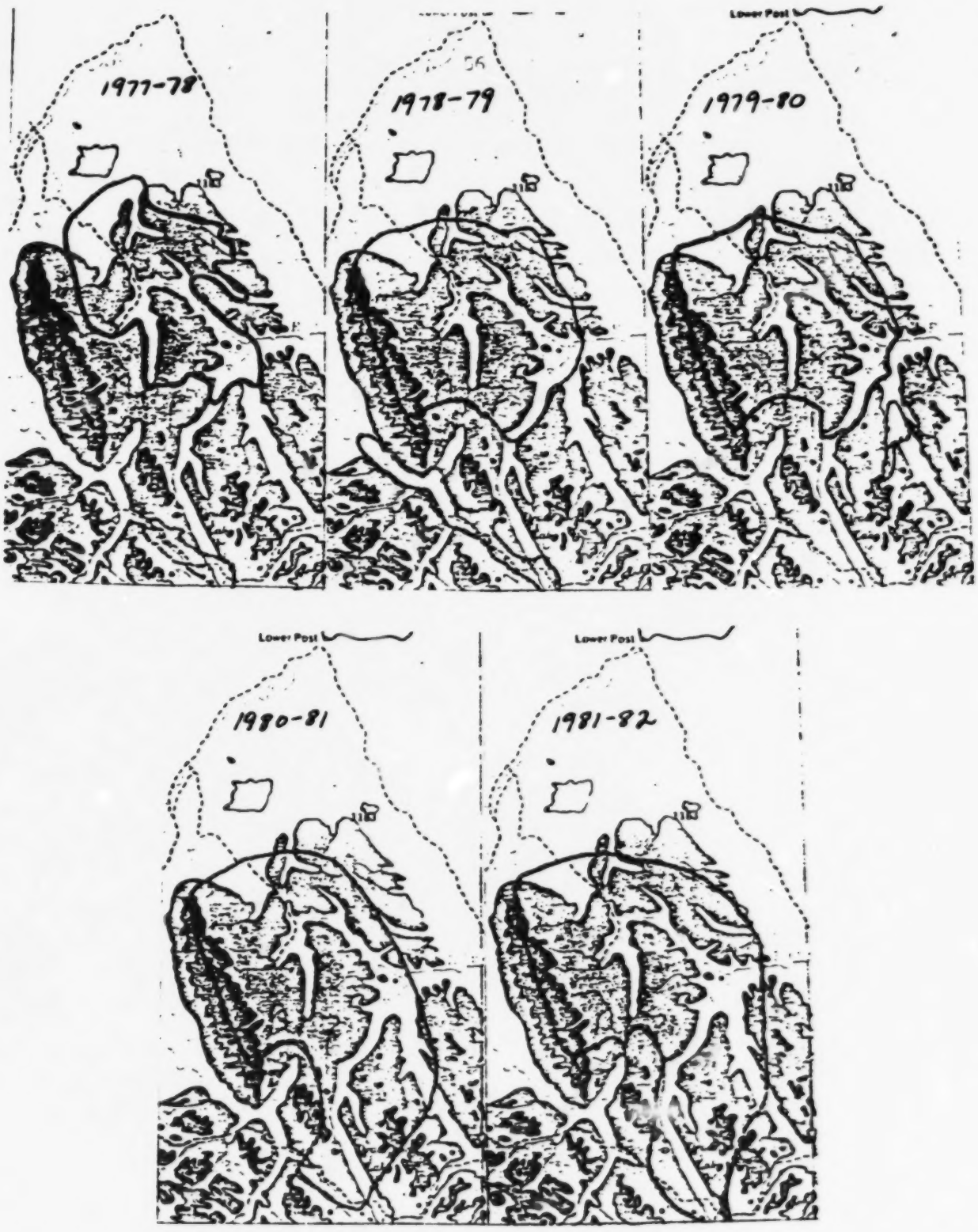


Fig. 14. Winter caribou distribution on the Horseranch Range Study area, 1977-82.

Table 18. Composition of moose survey samples, Level Mountain (1978-81) and Horseranch Range (1979-80).

Year	Study Area	Total moose	Bulls		Cows		Calves		
			no.	(%)	no.	(%)	no.	(%)	per 100[1] cows
1978	Level Mtn.	107	58	63	34	37	15	14	44
1979	Level Mtn.	148					33	22	--
	Horseranch	23	11	52	10	48	2	9	20
1980	Level Mtn.	50					14	28	--
	Horseranch	31	11	41	16	59	4	13	25
1981	Level Mtn.	92	23	30	53	70	16	17	30

[1] includes adult and yearling cows

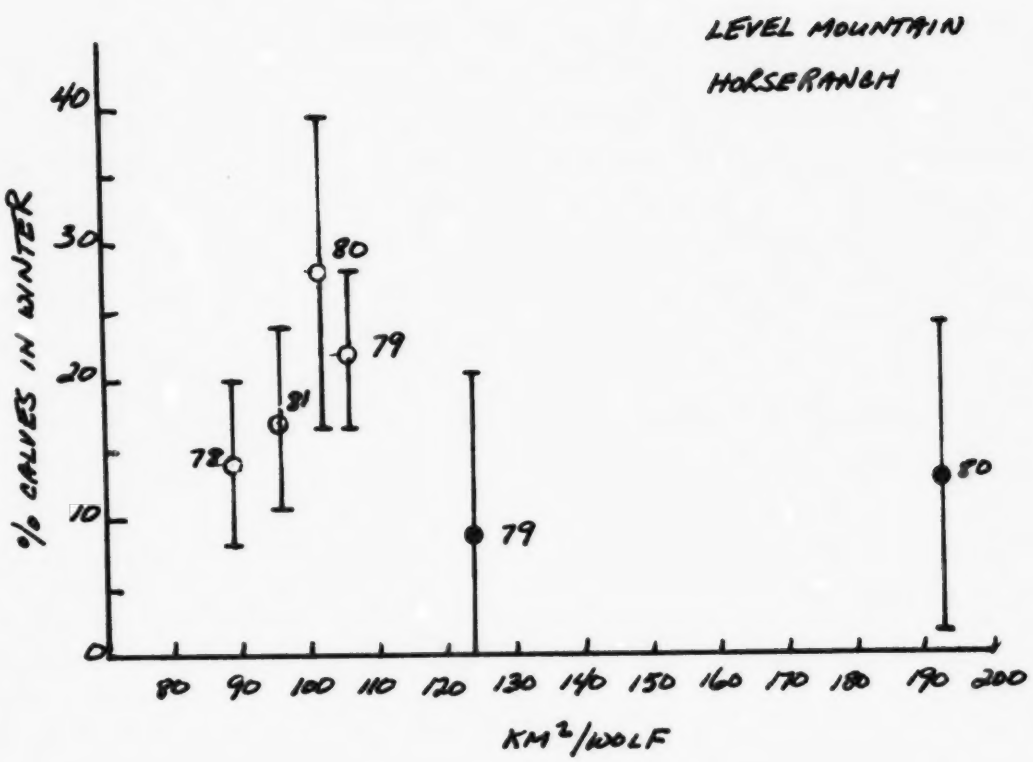


Fig. 15. Relationship between percent moose calves in winter and wolf density.

It was not possible to conduct a similar analysis for the Horseranch due to marked changes in wolf numbers from wolf control.

5.4.2 Population Size and Trend

On Level Mountain, the moose population showed an apparent rate of decline of 28% (r=-.33), to near 50% of the observed initial count (Table 19). Due to the high variability of the quadrat counts, however, all years have overlapping confidence limits (Fig. 16). On the Horseranch area, the moose population showed an apparent annual rate of increase of 60% (r=.47) from 1979 to 1980 (Table 20), coincident with wolf control and supported by the increase in calf recruitment in 1980. However, this apparent rate is biologically unrealistic, given r_m=0.34 (Bergerud 1978): statistically, the annual population estimates are not significantly different (paired t=.145 df=30, p>.50)(Fig. 16). Pooling population estimates from both years yielded a mean density of .39 moose/km^2 with 90% C.L. of .22 to .59 moose/km^2. Thus, at most these data should be used to suggest trends in numbers on both areas.

5.4.3 Annual Movements, Distribution and Habitat Relationships

For Level Mountain, moose wintering areas consisted mainly of the lower valleys on all sides of the study area (see census block stratification, Appendix 9, 10). In spring, cows with calves were seen in most of these same valleys, but many also moved to higher elevations, especially on the northwest end of the plateau. Summer and fall were spent primarily in subalpine habitats, although there were always animals in the lowlands as well. The degree to which moose on the Tuya, lower Tahltan, Tachilta Lakes, Nahlin River and Dudidontu Valley remained separate from each other or faithful to each area is unknown.

Table 19. Results of stratified random quadrat census for moose, Level Mountain, 1979-81.

Date	Stratum Size (mi^2)[1]			No. Moose[2]						No. Moose Projected[3,4]				Moose/km^2
				Low		Med		High						
	Low	Med	High	n	(x±SD)	n	(x±SD)	n	(x±SD)	Low	Med	High	Total	(± 90% C.L.)
Jan. 1979	788 (4)[1]	319 (11)	192 (15)	0	(0±0)	30	(2.73±2.65)	53	(3.53±4.32)	0	870	678	1548	.34 (35.6)
Mar. 1980	756 (5)	343 (10)	199 (15)	3	(0.60±.90)	2	(0.20±0.42)	42	(2.80±3.84)	454	69	557	1079	.24 (56.9)
Jan. 1981	788 (5)	323 (9)	187 (15)	0	(0±0)	8	(0.80±1.03)	36	(2.40±2.23)	0	258	449	707	.16 (36.4)
Feb. 1981	819 (5)	308 (10)	171 (15)	2	(0.40±0.55)	7	(0.70±1.16)	23	(1.53±1.64)	328	216	262	805	.18 (50.7)

1 low stratum excludes 1196 km^2 nil zone, no. of 1 mi^2 quadrats sampled is shown in parenthesis - total study area = 4559 km^2.

2 n = total number of moose seen in stratum while x is the mean number of moose per quadrat and SD is the standard deviation of the mean.

3 density times size of stratum = total projected number per stratum.

4 census block stratification for 1979 and 1981 shown in Appendix 9 calculations shown in Appendix 12

Table 20. Results of simple random block census of moose, Horseranch Study area, 1979-80.

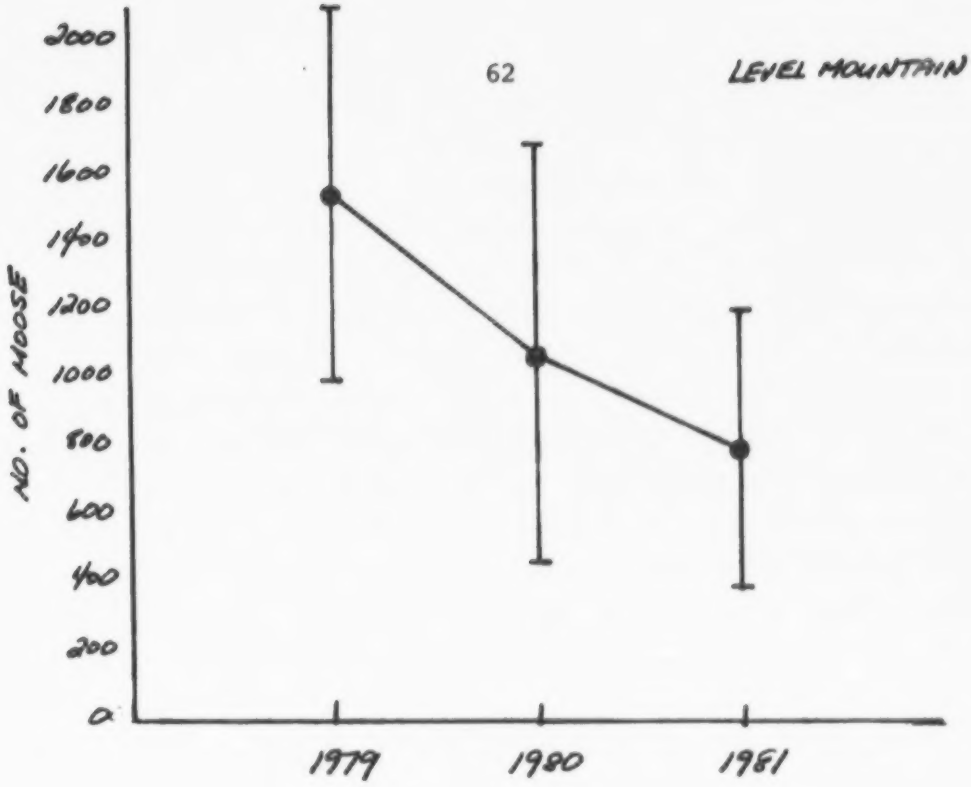
Date	No. Moose/block[1] (x ±SD)[2]	n	No. Moose[3] [4] Projected	Moose/km^2 (± 90% CL)
1979	1.38 ±2.81	23	466	.30 (±76.7)
1980	2.24 ±4.36	30	746	.48 (±75.0)
1979-80	1.81 ±2.73	27	606	.39 (±51.3)

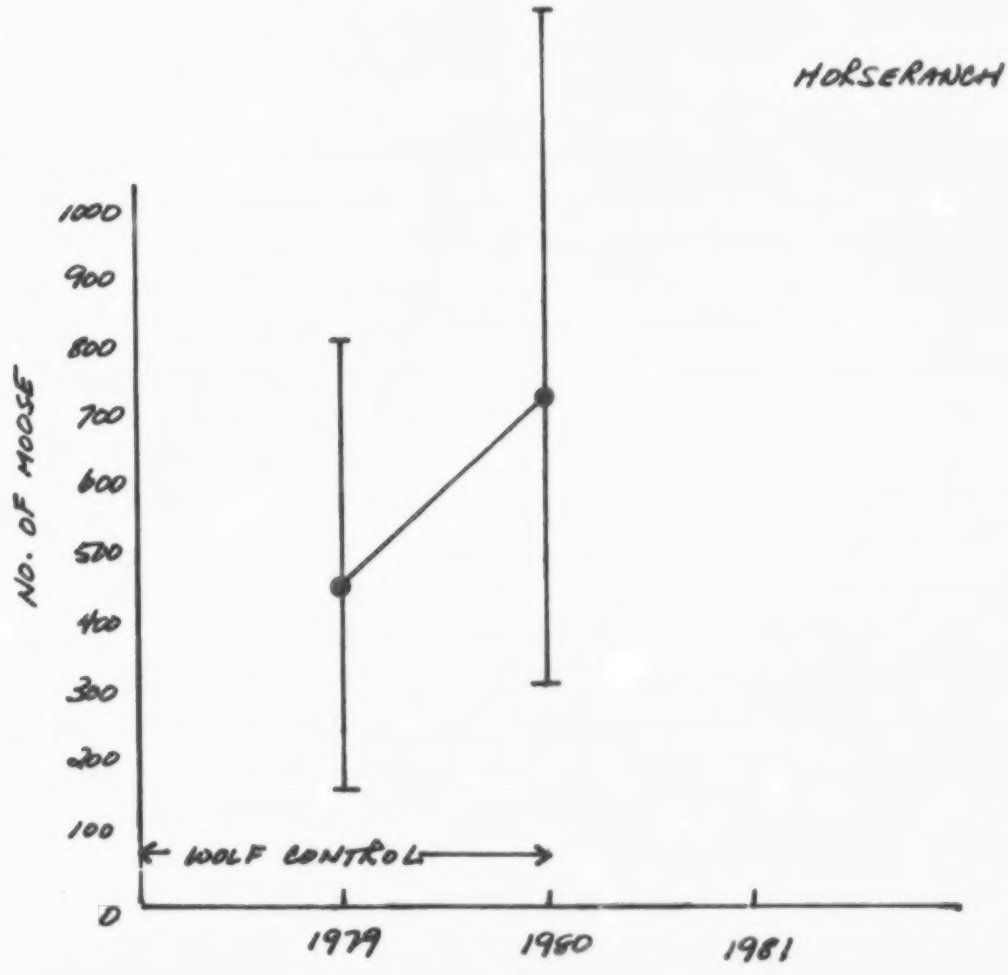
1 nil zone, above 1370 m, on the Horseranch Range excluded

2 n = total number of moose seen in the stratum, while x is the mean number of moose per block and SD is the standard deviation.

3 density times size of study area (1554 km^2) = total projected moose population.

4 census blocks shown in Appendix 11, calculation for 1979-80 shown in Appendix 13.


LEVEL MOUNTAIN
NO. OF MOOSE
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1979
1980
1981


HORSERANCH
NO. OF MOOSE
1000
900
800
700
600
500
400
300
200
100
0
← WOLF CONTROL →
1979
1980
1981

6. DISCUSSION

6.1 Impact of Weather on Calf Recruitment

This study has implicated weather as an important factor affecting neonatal calf recruitment of caribou. In addition to the antler cycle and possibly calving being more advanced following milder winters, a strong inverse relationship between neonatal calf recruitment and winter severity was found on the Horseranch Range. There was also some indication that weather during calving on Level Mountain affected neonatal recruitment and that snow, through restricting caribou calving areas, increased the susceptibility of calves to predation. Thus several different mechanisms through which weather affects calf recruitment can be hypothesized.

One hypothesis is that maternal nutrition, as influenced by late winter snow conditions lengthens gestation and affects intrauterine calf survival, neonatal calf viability and/or lactation by the cow. Verme (1965) has shown that white-tailed deer maintained on a low plane of nutrition have a lengthened gestation. Fetal resorption has been reported for several cervid species. Studies on white-tailed deer have shown that pregnant females subjected to grave nutritional stress during the late trimester of pregnancy, have retarded fetal development which reduces the fawns chances for survival at birth (Verme 1962, Verme 1963). Except for some stillbirths, the majority of the stunted fawns were reported to be born alive but died within a day or so because they were too weak to stand, too small to reach the teats; or because their mother abandoned them, delayed lactation, or did not lactate (Verme 1977). Increased neonatal mortality rates related to small birth weights have also been reported for elk (Thorne et al. 1976). For caribou, Bergerud (1975) concluded that gestation length and hence date of calving may vary between low plane and average nutritional diets. Fetal resorption, however, is not a major concern, since the nutritional stress for cows comes in late winter when fetuses are well developed and not subject to resorption. Although McEwan and Whitehead (1972), based on captive studies, speculated that an inverse relationship between calf size and survival (as mediated through winter weather influences on the cow) should also exist for caribou, Bergerud (1971) was unable to demonstrate this from field studies in Newfoundland. Although a negative correlation existed between caribou birth weights and the preceeding winter's snowfall, weights were not correlated with subsequent calf survival. The non-

correlation, however, may have been confounded by heavy lynx predation on calves (Verme 1977). Also small calves which Bergerud tried to raise invariably died (Bergerud 1979). In this study significant calf losses did occur following severe winters. However, it was not discerned whether following the more severe winters, smaller calves were born which subsequently died, whether calves were aborted or stillborn, or whether calves died due to reduced lactation by cows.

A second hypothesis is that inclement weather during calving causes pneumonia or other respiratory diseases resulting in the death of newborn calves. Studies on barren-ground caribou by McEwan (1959), Kelsall (1968) and Parker (1972) have documented the detrimental effects of windchill on new-born calves, primarily from strong winds, precipitation and low temperatures. Bergerud and Butler (1978), working in Spatsizi Park in northern B.C. found "no possibility" of windchill in 1977. However, an assessment of windchill mortality requires monitoring through a range of weather conditions during calving. We noted that the low neonatal survival rate in 1979 on Level Mountain was associated with severe weather conditions during calving and the high survival rate in 1980 with exceptionally mild conditions. Thus favourable weather during calving may mediate some of the nutritional effects incurred by pregnant females during a severe winter. Alternatively, inclement calving weather in combination with severe winters may produce a synergistic effect that results in markedly lower calf survival than the combined additive effects of each. Bos (1975) suggested that deep long-lasting snow and inclement weather during calving may cause significant neonatal mortality in barren-ground caribou.

A third hypothesis is that weather and wolves interact to affect calf recruitment. Deep spring snow packs can concentrate caribou calving and therefore could enable wolves to be more effective predators on new born calves. If predation is additive rather than compensatory wolves would be the principal cause of calf mortality with weather acting as one variable influencing the predator-prey interaction. Some support for this hypothesis comes from the 1979 calving season on Level Mountain since spring snowpack was severe, caribou concentrated and wolves denned in the calving area.

Unfortunately, the exact mechanism(s) through which weather affected neonatal recruitment in this study remains unknown and it is not possible to eliminate any of the above hypotheses. Indeed it appears that components of all of

the above hypotheses were operative to varying degrees during the study. It is our subjective impression that the subsequent effects of weather on maternal nutrition were most important, followed by the effects of calving weather, and finally through the interaction of spring weather and predation. Although weather is concluded to be an important factor affecting calf recruitment, it seems doubtful that it is capable of limiting caribou population growth in northern B.C. On the Horseranch Range, when wolf numbers were reduced, the caribou herd apparently continued to increase, despite several moderate to severe winters.

6.2 Impact of Predation on Calf Recruitment

Bergerud and Butler (1978) stressed the importance of predation on caribou calves during the calving period. Based on age composition data they indicated that in a little over one month, 92% of the calves in the Fire Flats area in Spatsizi Park during 1977 had died, despite at least 75% of the females having viable calves. Most of the calves appeared to have died within 10 days of the start of calving. By discounting other mortality factors such as disease, windchill and accidents, they were left by way of exclusion with predation as the principal cause of neonatal calf mortality. Wolves, grizzly bears, and wolverines were considered to be the major predators. Calves were also considered to be more susceptible to predation than adults throughout the summer and during their first winter of life. Moose, however, comprised the primary winter food source for wolves.

During this study predation was not considered to be important during caribou calving, although it was an important mortality factor on calves during the post-calving period (mid June to mid October). Wolf predation was considered to be most important, although grizzly bears, at least in 1980 on Level Mountain, were also significant (Page in prep.). The limited food habits analysis supports Bergerud and Butler's (1978) observations that caribou calves are the primary prey for wolves during summer and moose are the principal winter prey. It seems possible that this is a consistent pattern of wolf-moose-caribou systems in northern B.C. Switching prey types between seasons has also been documented elsewhere (Carbyn 1974, Peterson 1977).

Our results are consistent with the radiotelemetry calf mortality study conducted by Page (in prep.). Page found that 60% (n=11) of the radio-collared calves in Spatsizi in 1979 had died by the end of June, as opposed to 20% (n=21) on

Level Mountain in 1980. The rate of calf mortality on both areas remained constant from just after birth to the end of August, but dropped markedly during September and October. However only one of the six calves that died by 10 June was attributed to predation as opposed to all of the mortalities after this period. Four of the eight mortalities in 1979 occurred by 1979, June 10 whereas during the milder year in 1980 only 2 of 11 mortalities had occurred by this date. We agree with Bergerud and Butler (1978) that predation is primarily additive during the post-calving period. This is based on evidence that summer survival markedly increased following wolf removal.

In terms of the original hypothesis tested (reducing wolf numbers will increase recruitment in caribou), we conclude that wolf control can increase caribou calf recruitment but that significant increases will not be realized if severe weather conditions prevail. During the course of this study calf recruitment appeared to be affected more by weather than by wolf predation. However, had weather conditions been milder we expect that the relative effect of predation would have been greater.

6.3 Effectiveness of Wolf Control

Wolf control in local areas to maintain or enhance prey populations is considered a valid objective of wolf management in British Columbia (Fish and Wildlife Branch 1979). The success of a wolf control program can be judged from both the short term and long term benefits to the prey population(s). The short term benefits are increased recruitment and positive rates of increase, i.e. prey recovery. The longer term benefits accrue from a lag in wolf population growth relative to the prey population, allowing the prey to escape significant predation losses for several years. Achievement of short term benefits likely depends upon the intensity of wolf control and absence of confounding factors (e.g., weather) influencing recruitment. Achievement of long term benefits probably depends upon the method of wolf control used, the size of the wolf control area, the status of alternate prey populations and the initial response of the prey to wolf control. Failure to achieve long term benefits reduces the cost-effectiveness of wolf control.

Short term benefits of wolf control to the prey population(s) can be great as recently demonstrated in interior Alaska (Gasaway et al. 1983). Survival of calf

and yearling moose increased 2 to 4 fold, adult mortality declined sharply and the moose population increased. Survival of caribou calves also increased significantly and the population grew rapidly. Effective wolf removal and mild weather conditions likely speeded up the rate of recovery. In this study the short term benefits of wolf control for caribou were dampened by weather. Some positive effects, however, were still achieved. The Horseranch herd increased, albeit at a lower rate than the species intrinsic rate of increase, (r_m=0.30, Bergerud 1979) and the number of males increased over 3 fold during the course of the study. Although less certain, the moose population appeared to increase. Assessment of moose/wolf ratios by the method described by Keith (1983) suggests a substantial increase should have occurred (Appendix 15). One factor preventing the moose population response was the rapid immigration of wolves by mid-winter. Since wolf reductions did not commence until March, considerable wolf-related moose mortality probably took place during the control period. On the control area, both caribou and moose numbers decreased.

The long term benefits of wolf control to caribou in this study appear less certain. The Horseranch wolf population responded rapidly to the wolf reduction program and essentially had restored to their pre-control numbers within two years following termination of wolf control. Several reasons can be postulated for this. Random removal of individual wolves may have disrupted the social structure of packs resulting in increased breeding and pup recruitment (Haber et al. 1978). However, evidence that this occurs is still inconclusive (Gasaway et al. 1983). Alternatively, pack removal may result in increased immigration rather than expansion of adjacent pack territories. This seemed to be the case in 1979 and 1980 and probably was facilitated by the small size of the removal area and the presence of moose as an alternate prey. Haber and Walters (1979) have argued that given little or no decline in associated prey populations, a vacancy created by removing only several resident wolf packs is more likely to be filled by wolves from other regions than by territorial expansion of adjacent packs. Haber (1977) argues that such a situation results in an increase in predation on caribou, at least initially, because the new occupants are likely to be young dispersers arriving primarily in small groups or singly. Such animals are more successful in dealing with caribou than with large animals like moose. Pack sizes did appear to decline during the wolf reduction program and remained smaller during the post-control period. Haber and Walters (1978) believe that in such a situation an ongoing form of wolf control, probably once a year, aimed at complete suppression of the wolf

population impacting on caribou is required. Such a solution, however, should be evaluated economically and socially.

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Appendix 1. Environmental descriptions and vegetation lists of biophysical forest zones in the Level Mountain and Horsereach study areas (from Clements et. al. 1983).

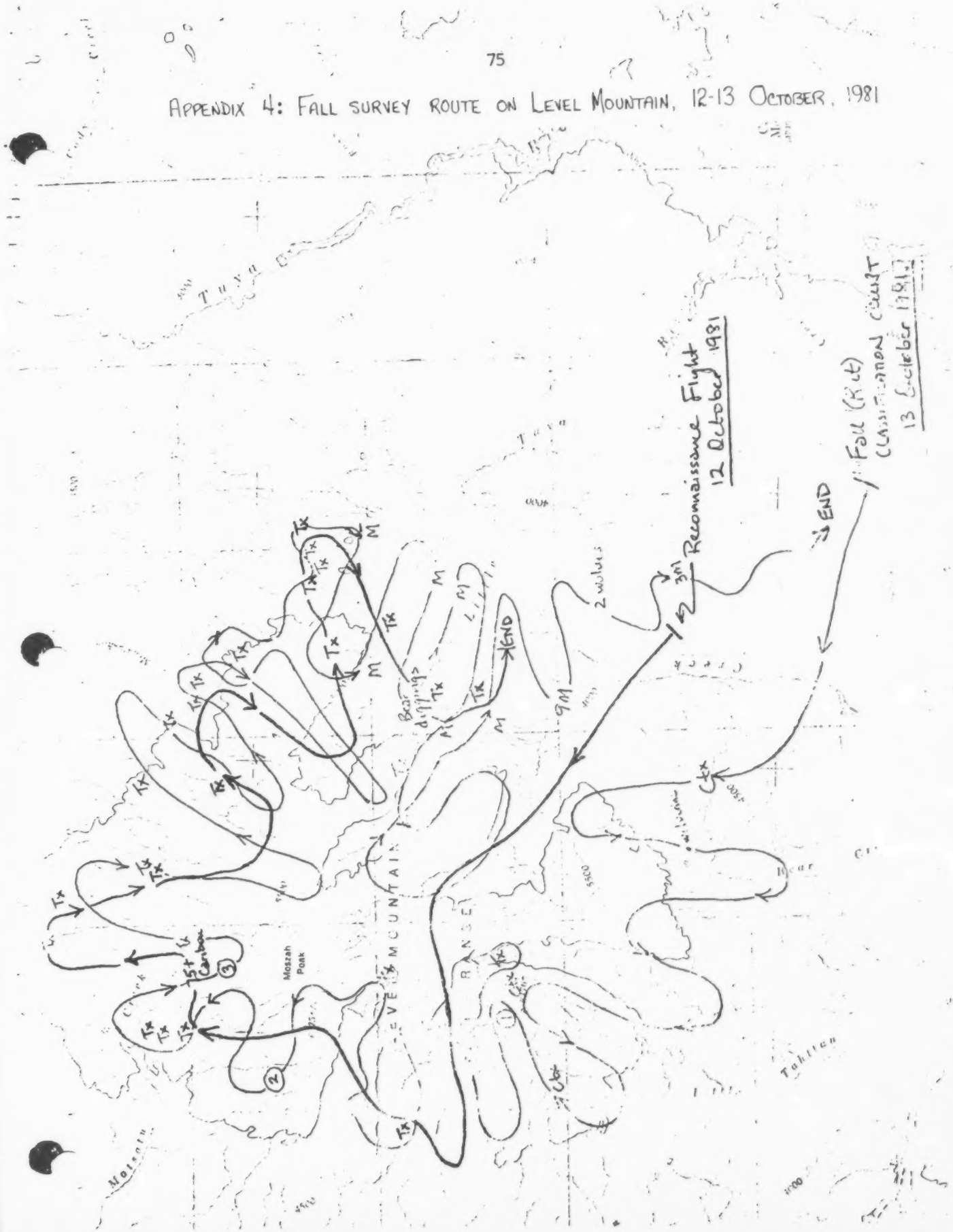
Boreal Forest Zone	Climatic Climax	Altitudinal Limits	Environmental Description	Level Mountain		Horsereach Range	
				Dominant Trees and Shrubs	Dominant Dwarf Shrubs, Herbs Mosses and Lichens	Dominant Trees and Shrubs	Dominant Dwarf Shrubs, Herbs Mosses and Lichens
Alpine Tundra	-	above 1540 m	-climatic conditions too severe for establishment of trees; -most of zone is dry and windswept -characterized by long, very cold winters, short, cold summers and moderate precipitation (based on the Cassiar station, mean daily temperature <-3.0°C, mean annual precipitation >700.4 mm, days with frost >265).	bog birch, willow	dwarf willows, Rotlerds kobresia, prickly saxifrage, boreal mugwort, Altai fescue, small-awned sedge, Arctic bluegrass, bluejoint small reed grass, sedges, rushes, step moss, Rhacomitrium mosses, Aulacomnium palustree moss, Tomenthypum nitens moss, Cladina mitis lichen, Cladina rangiferina lichen, Stereocaulon paschale lichen, Cetraria cucullata lichen, Alectoria sarmentosa lichen, Thamnolia subuliformis lichen, Cetraria islandica lichen.	willow	dwarf willows, four-angled cassiope, one-flowered cinquefoil, entire-leaved white mountain avens, loco weeds, boreal mugwort, Altai fescue, small-awned sedge, alpine wood rushes, Arctic bluegrass, Alpine sweet grass, sedges, rushes, cushion mosses, Polytrichum piliferum moss, Rhacomitrium mosses, sphagnum mosses, step moss, Aulacomnium palustle, Tomenthypnum nitens moss, Stereocaulon paschale lichen, Thamnolia subuliformis lichen, Cladonia unialis lichen, Alectoria ochroleucus lichen, Cetraria cucullata.
Subalpine Alpine Fir	Alpine fir	1200 to 1540 m	-long cold winters, short cool summers, and light to moderate precipitation (At Cassiar, mean daily temperature -3.0°C, mean annual precipitation 700.4 mm, days with frost 265)	alpine fir, bog birch, willows	sedges, step moss, Spagnum mosses, Tomenthypnum nitens moss, Polytrichum piliferum moss, Cladina mitis lichen, Cladina unclalis lichen, Cladina stellaris lichen, Cladina rangiferina lichen.	alpine fir big birch willows, bog blueberry	mountain cranberry, Canadian bunchberry, sedges, rushes, Altai fescue, small awned sedge step moss, running club-moss, common moss, cushion mosses, Polytrichum piliferum moss, Spagnum mosses, Tomenthypnum nitens moss, Cladina mitis lichen, Cladina unclalis lichen, Cladona gracilis lichen, Cladona cornuta lichen, Cetraria cucullata lichen, Stereocaulon paschale lichen.
Boreal White Spruce	White spruce	below 1200 m	-long cold winters, short, cool summers and light precipitation (At Dease Lake, mean daily temperature -1.2° C, mean annual total precipitation 394.4 mm, days with frost 224)	white spruce lodgepole pine, bog birch, willows, common labrador tea.	kinnikinnick, mountain cranberry, dwarf blueberry, Altai fescue, sedges, step moss, common moss, Spagnum mosses, Tomenthypnum nitens moss, Nephroma arcticum lichen.	white spruce, lodgepole pine, bog birch, willows, common labrador tea	kinnikinnick, mountain cranberry northern twinflower, mugworts, wheat grass, sedges, Altai fescue, step moss, Spagnum mosses, common moss, Tomenthypum nitens moss, Aulacomnium palustre moss, Drepano cladue unclatus moss, Cladina mitis lichen, Parmelia lichens.

Appendix 2. Morphological and condition measurements for wolves collected in the Horseranch Study area, 1979-80.

Specimen	Sex	Age	Body Weight (kg)	Kidney Weight (g)	Total Length (cm)	Neck Girth (cm)	Chest Girth (cm)	Hind Foot (cm)	Tail (cm)	Reproductive Status
1979										
79001	F	P	30.0	-	158	-	79	27	47	-
79002	F	P	32.3	-	161	47	72	27	47	-
79003	M	3	45.9	-	180	-	-	31	-	-
79010	M	3	50.5	125	193	58	93	31	45	-
79011	M	1	47.3	95	176	51	90	27	46	-
79012	F	2	42.7	126	170	60	95	27	41	In estrus
79013	M	7	48.4	134	178	54	94	28	43	-
79014	M	1	43.9	107	171	50	80	28	45	-
79015	F	P	31.8	101	168	45	80	28	48	-
79016	F	P	27.7	102	153	43	75	25	43	-
79017	M	3	44.1	135	194	60	90	28	54	-
79018	F	2	44.1	131	185	51	83	28	50	In estrus
79019	F	3	39.1	-	180	51	72	28	52	-
79020	M	P	39.1	-	177	47	69	29	50	-
79021	M	P	30.0	-	170	56	80	26	47	-
79022	M	P,Y	35.5	-	173	54	81	26	43	-
79023	M	P,Y	37.7	91	170	46	73	26	40	-
79024	F	5	42.7	170	180	50	77	28	41	In estrus
1980										
1056	M	2	52.2	143	170	50	75	29	40	-
1057	M	5	55.8	130	170	53	80	30	43	-
1058	F	2	38.1	124	151	50	67	29	42	In estrus
1060	F	1	41.7	111	162	57	75	28	42	-
1061	F	1	37.7	71	180	41	66	26	47	-
1062	F	1	41.7	69	169	53	71	26	48	-
1063	M	3	50.4	81	177	56	86	27	46	-
1064	F	6	40.4	28	145	55	78	27	40	-
1065	M	3	-	175	-	-	-	-	-	-
1066	F	3	-	120	-	-	-	-	-	-
1067	M	4	52.2	103	166	49	82	27	44	-
1068	F	2	50.4	112	162	47	75	28	39	-
1069	M	2	46.7	141	162	45	77	26	46	-
1070	M	7	55.8	-	164	48	92	27	43	-
1071	M	1	50.4	149	164	48	75	27	44	-
1072	F	P	34.5	54	155	38	67	26	43	-
1073	F	P	30.8	43	148	36	65	25	38	-
1075	F	P	32.7	70	146	37	68	25	41	-
1077	M	P	37.2	90	156	37	69	25	46	-
1079	M	P	39.0	44	146	40	72	26	39	-

APPENDIX 3: CALVING SURVEY ROUTE ON LEVEL MOUNTAIN, 9 JUNE 1981

APPENDIX 4: FALL SURVEY ROUTE ON LEVEL MOUNTAIN, 12-13 OCTOBER, 1981



APPENDIX 5: CALVING AND FALL SURVEY ROUTES ON HORSERANCH RANGE.

Appendix 6. Population projection for the Level Mountain caribou herd, based on 1978 census estimate and observed five month recruitment (see text).

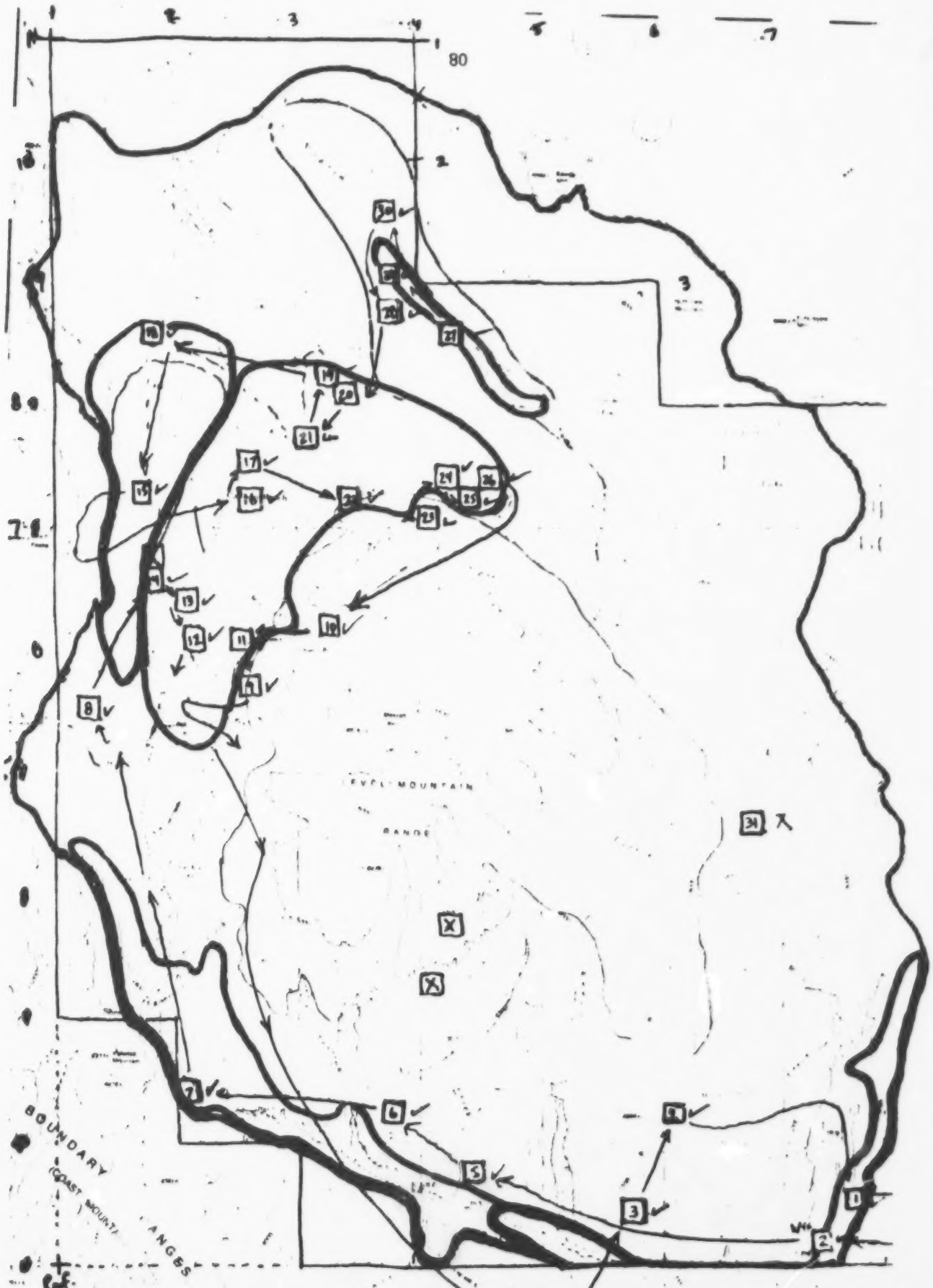
Year	Pre-hunt Population Exp.	Harvest	Post-hunt Population Obs	Post-hunt Population Exp.	Post-hunt Population Obs % calves	% Yrlgs	Adult q_x %	Adult q_x no.	Spring Pop Obs	Spring Pop Exp
1977	224	10	228	214	5.7	3.7	12.4	25	--	184
1978	241	12	229	229	24.9	22.9	5.0	9	113	211
1979	232	10	286	222	9.4	7.4	10.9	22	128	193
1980	229	9	184	220	16.3	14.3	8.3	15	113	197
1981	210	7	108	203	6.5	4.5	12.1	23	99	175
1982	176	10	129	166	0.8	0	14.3	24	--	141

Appendix 7. Population projection for the Horseranch Range caribou herd, based on 1978 census estimate and observed five month recruitment (see text).

Year	Pre-hunt Population Exp.	Harvest	Post-hunt Population Obs	Post-hunt Population Exp.	Post-hunt Population Obs % calves	% Yrlgs	Adult q_x %	Adult q_x no.	Spring Pop Obs	Spring Pop Exp
1977	265	5	237	260	6.3	4.3	12.1	30	--	224
1978	268	5	263	263	16.7	14.7	8.1	18	256	236
1979	284	6	274	278	17.2	15.2	7.9	18	240	250
1980	297	4	311	293	16.1	14.1	8.4	21	175	262
1981	294	3	329	291	10.9	8.9	10.4	27	221	255
1982	266	5	337	261	4.2	2.2	13.0	37	125	223

Appendix 8. Description of vegetation landscapes occurring on late winter-early spring caribou ranges on Level Mountain and the Horseranch Range.

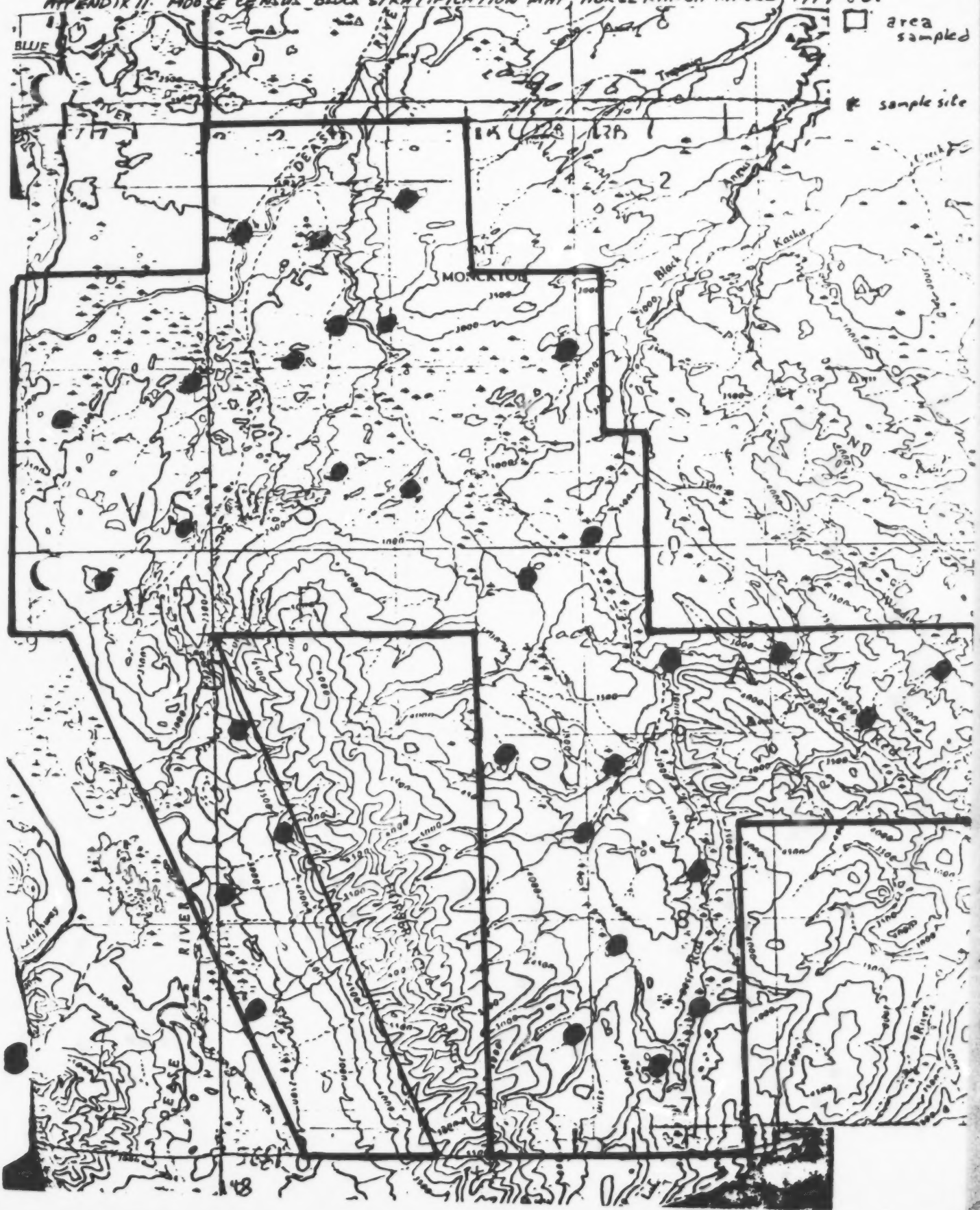
Map Symbols		Vegetation Landscape Name	Surficial Material	Moisture Regime	Principal Process[1]	Stand Appearance[2]	Dominant Plants[3]		Associated Plants		Comments
Region and Line	Vegetation Landscape						Trees and Shrubs	Dwarf Shrubs, Herbs, Mosses and Lichens	Trees and Shrubs[4]	Dwarf Shrubs, Herbs, Mosses and Lichens	
	68	taberetia	eluvial veneers	xeric to mesic	pioneer seral, climatic climax	tundra	none	dwarf willows, Bolton's taberetia, Altai fescue, shelf-awned sedge, Polytrichum piliferum moss, Cetraria cucullata lichen, Alectoria sarmentosa lichen, Ingamella tubaeformis lichen	dwg birch, willows	Arctic blue grass, Arctic lupine, alpine sweet grass, entire-leaved white mountain avens, Stereocaulon paschale lichen, Cetraria islandica lichen	Low to middle elevations on alpine tundra zone, often on exposed ridges. Soils are usually moist, well drained and moderately acidic. Nutrient cycling is very slow.
	85	rubble - sedge	eluvial blankets and veneers, colluvial blankets, veneers and aprons	xeric to mesic	pioneer seral	sparse forbs	none	dwarf willows, shelf-awned sedge, prickly saxifrage, Cetraria islandica lichen, Cetraria cucullata lichen	none	Altai fescue, moss campion, alpine bistort, Arctic blue grass, Polytrichum piliferum moss, Stereocaulon paschale lichen, Alectoria sarmentosa lichen	High elevations on alpine tundra, on lower slopes of an ironic environ ments. Soils are usually poorly developed and very coarse textured. But productivity is increased by addition of nutrient enriched seepage water
	86	rubble - blue grass	colluvial blankets and veneers, steep rock slopes	xeric	pioneer seral	sparse forbs	none	Arctic blue grass, sedges, Rhacomitrium mosses, Alectoria sarmentosa lichen	none	arctic saxifrage, various mosses, Cetraria cucullata lichen	Highest elevations in alpine tundra, on colluvial slopes. Soils are shallow to lacking. Sites are extremely arctic and xeric. Very low nutrient availability
	88	sedge - willow	fluvioglacial undulating, eluvial blankets	hydric	edaphic climax	wetlands, open shrub	willows	bluejoint small reed grass, sedges, rushes, Aulacomnium palustre moss, Tomenthypnum nitens moss	none	alpine bell Jacob's-ladder, various mosses	Highly variable wetland complex in which one or dominant species listed may dominate. Waterlogged soils at surface for most of growing season, sites are usually acidic.
	89	willow - moss	eluvial blankets, colluvial blankets and veneers	mesic to hydric	climatic climax	open shrub, tundra	willows	dwarf willows, shelf-awned sedge, Sphagnum mosses, sibe moss, cushion mosses, Polytrichum piliferum moss, Cetraria cucullata lichen	none	mountain cranberry, snow-runnels, alpine sweet grass, Arctic blue grass, Aulacomnium palustre moss, Cladonia uncialis lichen, Cetraria islandica lichen	Typical vegetation on lower rectolene alpine slopes. Sites are often nutrient enriched as a result of seepage, ranking lower slopes in the tundra lower which has higher available nitrogen than adjacent mineral soil
	3a	dwarf willow	colluvial blankets and veneers (occurs rarely on gentle to steep rock slopes)	xeric	climatic climax	tundra	none	dwarf willows, sedges, Polytrichum piliferum moss, Ingamella tubaeformis lichen, Cladonia uncialis lichen	none	Arctic blue grass, alpine sweet grass, boreal dryopteris, moss campion, Cetraria pinastri lichen, Alectoria ochroleuca lichen	High elevations below rock slopes. Soils are frozen for much of the year and as a result nutrient cycling is very slow. On the western slopes soils are high in calcium
	4a	mountain avens	eluvial blankets, colluvial veneers and aprons	xeric	pioneer seral	tundra	none	entire-leaved white mountain avens, shelf-awned sedge, lousewort, Alectoria ochroleuca lichen	none	mountain cranberry, alpine-azalea, Arctic lupine, dwarf willows, Cetraria cucullata lichen, Ingamella tubaeformis lichen	Typical vegetation on middle alpine elevation exposed rubble soils. Soils are very coarse and low in nutrients



APPENDIX 9 MOOSE CONTROL RUCK CLASSIFICATION MAP. LEVER MTN. 1979

APPENDIX 10. MOOSE CENSUS BLOCK STRATIFICATION MAP, LEVEL MTN, 1981

APPENDIX II. MOOSE CENSUS BLOCK STRATIFICATION MAP, HORSE RANCH RANGE, 1979-80.



Appendix 12. Arrangement of calculations to obtain moose population estimates and 90% confidence intervals for Level Mountain.

A. Summary Data

Date	Strata	N_h	n_h	$\bar{x}_h$	s_h^2	w_h	$w_h s_h^2$	$\frac{w_h^2 s_h^2}{n_h}$	$\bar{x}_h w_h$
Mar 1979	Low	788	4	0	0	.607	0.000	0.000	0.000
	Mod	319	11	2.727	7.017	.246	1.726	0.037	0.671
	High	192	15	3.53	18.66	.147	2.743	0.027	0.579
	N	1299	30			1.000	4.469	0.066	1.250
Mar 1980	Low	756	5	0.600	0.81	.582	0.472	0.055	0.349
	Mod	343	10	0.200	0.176	.264	0.466	0.001	0.053
	High	199	15	2.800	14.746	.153	2.261	0.231	0.429
	N	1298	30			1.000	2.779	0.793	0.831
Jan 1981	Low	788	5	0	0.000	0.607	0.000	0.000	0.000
	Mod	323	9	0.800	1.061	0.249	0.264	0.007	0.199
	High	187	15	2.400	4.973	0.144	0.717	0.007	0.346
	N	1298	29			1.000	0.981	0.142	0.545
Feb 1981	Low	819	5	0.400	0.300	0.631	0.189	0.024	0.252
	Mod	308	10	0.700	1.344	0.237	0.319	0.008	0.166
	High	171	15	1.533	2.695	0.132	0.356	0.003	0.202
	N	1298	30			1.000	0.864	0.035	0.620

Definitions

N_h = Total number of sampling units for each stratum
n_h = Number of sampling units that were sampled from each stratum
$\bar{x}_h$ = Strata means
s_h^2 = Strata variances
w_h = Strata weights (N_h/N)
X = Estimated population total for study areas
N = Total number of sampling units

B. Calculations

(i) Population Estimate $\bar{X} = \bar{x}_{st} N$

(ii) $s^2_{\bar{x}st} = \sum \frac{w_h^2 s_h^2}{n_h} - \frac{\sum w_h s_h^2}{N}$

(iii) 90% confidence limits for population estimate $X \pm t_{0.10} N s_{\bar{x}st}$

Date	X	$s_{\bar{x}st}$	90% CL_1	90% CL_2
			No. of Moose	
Mar 1979	1545	.0621	994	2096
Mar 1980	1079	.0707	465	1693
Jan 1981	707	.0134	451	964
Feb 1981	805	.0343	395	1215

Appendix 13. Arrangement of calculations to obtain moose population estimates and 90% confidence intervals for Horseranch.

A. Raw Data

Block	Area (mi^2)	No. Moose 1979	No. Moose 1980	Moose/mi^2 1979	Moose/mi^2 1980
1	0.4125			0	0
2	0.3100		2	0	6.452
3	0.3850	4		10.390	0
4	0.2250		4	0	17.778
5	0.9600			0	0
6	0.8475			0	0
7	1.7375			0	0
8	0.4975		2	0	4.020
9	0.4950	4	1	8.081	2.020
10	0.3775	2	2	5.298	5.298
11	0.5675			0	0
12	0.3575			0	0
13	0.8700	1		1.149	0
14	0.2750		1	0	3.636
15	0.4250		1	0	2.353
16	0.4450			0	0
17	0.5275	2		3.791	0
18	0.5250			0	0
19	0.1950			0	0
20	0.6200			0	0
21	0.5500			0	0
22	0.4400	1	1	2.273	2.273
23	0.6750	3		4.444	0
24	0.5575			0	0
25	0.5025			0	0
26	0.3225			0	0
27	0.2225			0	0
28	0.6854		1	0	1.459
29	0.8142	6	10	7.369	12.282
30	1.0149			0	0
31	0.4166		5	0	12.002
Σ	17.2461	23	30		

B. Calculations

i) Transformed Data, using $X = \sqrt{X + 0.5}$

	1979	1980
$\bar{X}$	1.127	1.325
SS	18.888	30.652
S.D.	.793	1.011
n	31	31
S.E.	.143	.182
90% L_1	.886	1.017
90% L_2	1.369	1.633

ii) Transform back to original units, moose/mi ^{2}

	1979	1980
$\bar{X}$	.771	1.255
90%L_1	.284	.534
90%L_2	1.374	2.167

iii) Calculate Best Estimate, pool 1979 and 1980

a) $\bar{X}_p = \frac{n_1\bar{X}_1 + n_2\bar{X}_2}{n_1 + n_2} = \frac{31(.771) + 31(1.255)}{31+31} = 1.01$ moose/mi^2 x 600 mi^2 = 606 moose

b) 90% C.L. for Best Estimate

$\bar{X}_p \pm t_{\alpha/2(2),(n_1+n_2)}\sqrt{\frac{s^2_p}{n_1+n_2}} = 1.013 + .5 \pm 1.671\sqrt{\frac{.926}{31+31}} = 1.23 \pm .193$

c) Transform back to original units

L_1 = .58 moose/mi ^{2} x 600 mi ^{2} = 348 moose
L_2 = 1.52 moose/mi ^{2} x 600 mi ^{2} = 912 moose

Appendix 14. Calculation of 12 month calf (short-yearling) recruitment rates for moose on Level Mountain.

Assumptions

1) wolves kill calves at about twice their abundance in the population during the first winter of life (Haber 1966, Wolfe 1977, Peterson 1974- cited by Bergerud and Butler (1978)

2) consumption rate = 8.5 moose/wolf/year or .7 moose/wolf/month (Keith 1983)

3) wolves continue to prey on moose for 3 1/2 months (Feb 1 - May 15)

Year	Winter Moose		% calves	Wolves	Moose Killed		Spring Moose		% Calves
	Adults	Calves	(Feb. 1)		Adults	Calves	Adults	Calves	(May 15)
1979	1207	341	22	44	60	48	1147	293	20
1980	777	302	28	45	48	62	729	240	25
1981	627	129	17	48	78	40	549	89	14

Appendix 15. Calculation of wolf reduction expected to stabilize the Horseranch moose population.

Keith (1983) indicated that the relationship between moose numbers, wolf predation, and hunting can be summarized from the following simple numerical model:

$$N = \frac{K}{(\lambda-1)(1-H)}$$

where N = moose numbers per wolf in spring before births

λ = potential finite rate of increase of moose

H = proportion of the annual increment of moose removed by hunting

K = number of moose killed per wolf annually.

This assumes that wolf predation and hunting mortality are additive and do not merely replace other mortality factors. Keith (1983) suggest that for moose, K=8.5 moose/wolf/year. The kill rate assumes that any tendency for the moose kill to drop in summer (in this case, use of caribou as an alternate prey), is offset by the much smaller size of moose killed (usually calves). If λ=1.20 and H=0.2 (our best estimates), then the moose:wolf ratio needed to produce a stationary moose population on the Horseranch would be 53 moose/wolf. Observed moose:wolf ratios ranged from 21 moose/wolf before control (27-29 wolves:606 moose) to 152 moose/wolf following control (4 wolves:606 moose). According to Keith's equation 17 wolves would be required to stabilize the moose population, or a 40% reduction in the wolf population. Although the realized reduction was about 85%, only a 7% reduction was achieved from Mar. 1979 to Mar. 1980, due to immigration of wolves. If only 4 wolves remained following the above parameters suggest that the finite rate of increase should have been λ=1.10

eg. after calving:606 x 1.20 = 727 moose

predation: 4 wolves x 8.5 moose/wolf/year = 34 moose killed

hunting: (727-606) x 0.2 = 24 moose shot

before calving: 727-34-24=669 moose, λ=669/606=1.10

POOR

QUALITY

ORIGINAL